DISINTEGRATION OF HYPERFRAGMENTS

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A search has been made for the hyperfragments produced by 500 MeV/c K^--meson in nuclear emulsion. A large number of events have been found. The present paper reports an analysis of five of them. This includes one case of non-mesonic decay of a helium hyperfragment. The binding energy found in each case is in agreement with the value obtained at other laboratories.

Introduction

Following the discovery by Danysz and Pniewski of the existence of hypernuclear systems, stable for times comparable with the free Λ°-lifetime, many events have been reported and binding energy of the Λ°-hyperon evaluated by different workers. Our knowledge of the Λ°-nucleon interaction has come primarily from these observations.

Therefore it seems worthwhile to undertake a programme for the systematic study of hyperfragments produced by 500 MeV/c K^--mesons in flight in order to obtain additional information on the interaction of the Λ°-particle in various nuclei.

A detailed description of five events are presented in this paper.

Procedure

The 500 MeV/c K^--plates obtained from Berkeley are area-scanned for stars with a low magnification ($12.5 \times 10 \times$). After a star is found, the grey and black tracks are followed until they either leave the emulsion or stop. Connected stars are then studied under a high magnification ($12.5 \times 100 \times$).

Whenever a direct measurement of charge by usual methods is not possible, an estimate of the charge of the hyperfragments has been made by assuming that the total visible charge from the fragment disintegration is equal to the charge of the fragment.

The binding energy, in general, can be found out from the expression,

$$B.E.\ (\Lambda^\circ) = (m_\Lambda c^2 + m_i c^2) - (\Sigma_f m_f c^2 + Q)$$

where m_Λ, m_i denote the total rest energy of the Λ°-particle and of the nucleus to which it is bound and m_f denotes the mass of a final unclear fragment (or pion), the sum f being over-all fragment (including the pion) of the final system.

Observations

Event 1:

The hyperfragment is found to be 990 microns long. The delta rays along it and the lack of thinning down near the end shows that it has a charge 3 or 4. The hyperfragment decays into tracks 1 and 2. The appearance of the track 1 gives its charge as 1 or 2. The track 2 appears to have been produced by a particle of unit charge. The grain density count shows it to be deuteron. Consequently track 1 may be due to He^3 or He^4.

If the residual momentum of the two visible decay particles is given to be one neutron, the decay can be interpreted as

$$_\Lambda Li^6 \rightarrow He^3 + d + n + Q_1, Q_1 = 154 \text{ MeV},$$
$$B.E.\ (\Lambda^\circ) = 5.3 \pm 2.5 \text{ MeV}$$

or

$$_\Lambda Li^7 \rightarrow He^4 + d + n + Q_2, Q_2 = 170 \text{ MeV},$$
$$B.E.\ (\Lambda^\circ) = 5.1 \pm 2.5 \text{ MeV}$$

The details of the tracks are given in Table 1.

Event 2:

The hyperfragment decays after travelling a range of 105 microns of emulsion. From the scattering at the end it appears that the hyperfragment came to rest before decay. The tracks are all coplanar. Of the three decay tracks, track 1 can be indentified with a proton from its appearance. Track 3 shows the characteristic multiple scattering and change in grain density of a pi-meson. It has a range of about 13,000 microns and low energy electron tracks are associated at the end of its range.

If the residual momentum of the proton and pi-meson is given to a He^3 or He^4 nucleus, their expected ranges would be 2.9 and 2.7 microns, respectively. The disintegration can then be written as either

TABLE 1.—SUMMARY OF EVENT 1.

Track	Range in microns	Probable identity	Energy in MeV	Angle in decay plane
Hyperfragment	990	${}_{\Lambda}Li^6$ or ${}_{\Lambda}Li^7$	104.5 or 112.5	
Track 1	235	He^3 or He^4	22 or 25	} 100°
Track 2	5700	d	52	

Energy of the neutron $E_n = 80$ MeV if ${}_{\Lambda}Li^6$ or $E_n = 93$ MeV if ${}_{\Lambda}Li^7$.

TABLE 2.—SUMMARY OF EVENT 2.

Track	Range in microns	Probable identity	Energy in MeV	Angle in decay plane
Hyperfragment	105	${}_{\Lambda}He^4$ or ${}_{\Lambda}He^5$	14 or 17.5	
Track 1	280	p	7	
Track 2	2.3	He^3 or He^4	0.5 or 0.7	125°
Track 3	13000		26	80°

TABLE 3.—SUMMARY OF EVENT 4.

Track	Range in microns	Probable identity	Energy in MeV	Angle in decay plane
Hyperfragment	2	${}_{\Lambda}He^4$		
Track 1	28000	p	95 MeV	} 130°
Track 2	800	d	17	

$E_n = 57$ MeV

TABLE 4.—SUMMARY OF EVENT 5.

Track	Range in microns	Probable identity	Energy in MeV	Angle in decay plane
Hyperfragment	1000	${}_{\Lambda}Li^6$ or ${}_{\Lambda}Li^7$	105 or 113	
Track 1	240	He^3 or He^4	22.5 or 26.0	} 100°
Track 2	5680	d	52.0	

$En = 80.4$ MeV. if ${}_{\Lambda}Li^6$ and $E_n = 93.5$ MeV. if ${}_{\Lambda}Li^7$

$_{\Lambda}He^4 \rightarrow He^3 + p + \bar{\pi}$ giving B.E.(Λ°)=3.3 ± 1.0

or

$_{\Lambda}He^5 \rightarrow He^4 + p + \bar{\pi}$ giving B.E.(Λ°)=3.15±1.0

The details of the decay are summarized in Table 2.

Event 3:

The hyperfragment comes to rest and decays into two visible tracks 1 and 2. Gap and delta ray counting gives it to be a particle of charge 2. Track 1 is found to have a range of about 1500 microns and is identified with a proton track, the energy being 18 MeV. The recoil track 2 appears to have a range of 10 microns and since the hyperfragment has charge 2 the recoil will have unit charge; so it is either a deuteron or a triton, the energy being 1.0 MeV or 1.1 MeV.

This represents a case of non-mesonic decay of a helium hyperfragment.

Event 4:

A slow unstable particle comes to rest after travelling about 2 microns in emulsion. It disintegrates to give rise to two charged particles. Track 1 gives the general appearance of a proton track and has a range of 28000 microns. This is confirmed by multiple scattering measurement.

Track 2 has a range of about 800 microns. The complete absence of delta rays and the scattering at the end is typical of a singly charged particle coming to rest and comparison with nearby ending proton tracks gives it as singly charged. Multiple scattering measurement shows it has a mass of about 3200 m_e; so it may be a deuteron. Noncoplanarity of the decay suggests the emission of a neutron.

The hyperfragment then has a charge 2. The energy of the proton is about 95 MeV and that of deuteron about 17 MeV, the angle between them being about 130°C. The neutron balancing the momentum will have a kinetic energy of 57 MeV. The disintegration can then be written as

$_{\Lambda}He^4 \rightarrow p + d + n + Q$, $Q = 168 \pm 0.8$ MeV

B.E. (Λ°) = 2.2 ± 0.8 MeV

Details of the disintegration are summarized in Table 3.

Event 5:

This event is found to be similar to the event No. 1. The hyperfragment comes to rest after about 1000 microns and produces tracks 1 and 2. The hyperfragment is found to have a charge 3 or 4. Track 2 is produced by a particle of unit charge. Hence track 1 is either He^3 or He^4. The decay can be written as either

$_{\Lambda}Li^6 \rightarrow He^3 + d + n + Q_1$, $Q_1 = 153$ MeV

B.E. (Λ°) = 5.1 ± 2.0 MeV.

or

$_{\Lambda}Li^7 - He^4 + d + n + Q_2$, $Q_2 = 168$ MeV

B.E. (Λ°) = 5.0 ± 2.0 MeV.

The details are summarized in Table 4.

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