occurred, solar activity data[2] indicated the greatest outbreak of active regions since 1951. The mean of the daily averages from February 11 to 27 inclusive is 830 hr^{-1}, which is greater than the average of the preceding period, February 1–10, indicating that there is an average net increase of low-energy primaries and not a redistribution in time of the existing cosmic-ray flux.

These intensity-time variations of the nucleonic component of cosmic radiation will be reported later in more detail.

[2] Solar activity data furnished by High Altitude Observatory and National Bureau of Standards, Boulder, Colorado.

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Two Hyperfragments from Negative K-Particle Capture and the Mass of the Negative K Particle*

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Two hyperfragments are described which have been found from 81 negative K-particle interactions at rest and in flight. Event 35 was identified as a K^- capture in carbon which emitted a ${}_\Lambda Li^7$ hyperfragment that decayed into a π^- meson and a Be^7 fragment. The binding energy of the Λ hyperon in ${}_\Lambda Li^7$ was found to be 4.4 ± 0.7 Mev. The mass of the negative K particle which was captured in this reaction was found to be 966.2 ± 5.0 electron masses. In Event 71, a negative K particle was captured in a light nucleus. Four charged particles and a π^- meson and a hyperfragment, ${}_\Lambda He^4$, left the K^- ending. The ${}_\Lambda He^4$ decayed into a proton, a π^- meson, and a He^3 fragment. The binding energy of the Λ hyperon in ${}_\Lambda He^4$ was found to be 1.5 ± 0.6 Mev.

A STACK of 112 Ilford $G.5$ emulsions, each 6 in. $\times$6 in.$\times$600μ thick, has been exposed to the "negative K-particle beam"[1] with momenta of 270 to 380 Mev/c at the Berkeley Bevatron. Among 81 negative K-particle interactions at rest and in flight that have been found in this experiment there are two examples of hyperfragment emission, herein designated as Events 35 and 71.

EVENT 35

In this event, drawn in Fig. 1, a negative K particle was captured at rest in a light element of the emulsion.[2]

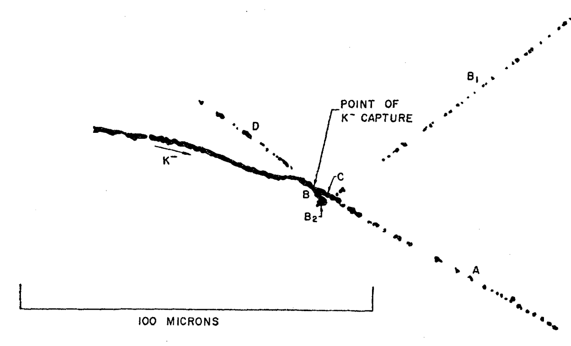

FIG. 1. A drawing of the decay of a ${}_\Lambda Li^7$ hyperfragment (track B) into a π^- meson (B_1) and a Be^7 nucleus (B_2). The ${}_\Lambda Li^7$ comes from the capture of a negative K particle in a C^{12} nucleus producing a π^- meson (A), a He^4 (C), and a proton (D) (Event 35).

From the star were emitted a proton (D), a hyperfragment (B), a short prong (C), and a light meson (A) that escaped through the edge of the stack approximately 1 mm from the end of its range. The hyperfragment decayed into a π^- meson with a range of 2.19 cm and a recoil of 2 microns range.

The identities of prongs A, B_1, and D were obtained from ionization, scattering, and range measurements. The identities of prongs B, B_2, and C and the charge of prong A (π) were inferred from the following K^- capture and hyperfragment decay reactions:

$$K^-+C^{12}\rightarrow\pi^-+{}_\Lambda Li^7+He^4+H^1+Q_1, \quad (1)$$

$${}_\Lambda Li^7\rightarrow\pi^-+Be^7+Q_2. \quad (2)$$

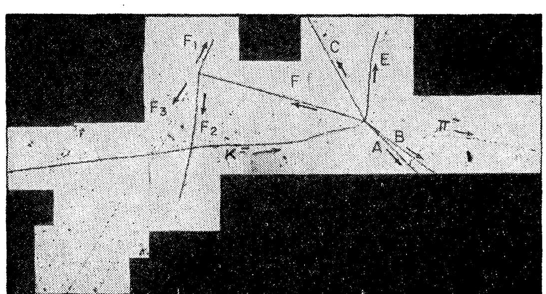

FIG. 2. A photomicrograph of the decay of a ${}_\Lambda He^4$ hyperfragment (track F) into a He^3 (F_1), a proton (F_2), and a π^- meson (F_3). The ${}_\Lambda He^4$ is emitted from the capture of a negative K particle, yielding, in addition to the hyperfragment, four charged particles (A, B, C, and E) and a π^- meson (Event 71).

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] Kerth, Stork, Haddock, and Whitehead, Phys. Rev. **99**, 641(A) (1955).

[2] The energies of the short prongs (B and C) lie below the Coulomb barrier for the heavier elements in the emulsion.

TABLE I. Measurements from Event 35.

Track	Identity	Range (μ)	Energy (Mev)	Momentum (Mev/c)
A	π^- [a]	$>34\,000$	49.7 ± 1.9	128 ± 6
B	$_\Lambda Li^7$	6.3 ± 1.0	2.80 ± 0.20	191 ± 7
C	He^4	8.7 ± 1.0	2.50 ± 0.20	137 ± 6
D	H^1	$29\,290\pm400$	96.6 ± 0.7	437 ± 3
B_1	π^-	$21\,950\pm700$	37.2 ± 0.7	108 ± 1
B_2	Be^7	2 ± 1 [b]	0.89 ± 0.02	108 ± 1

[a] The π^- left the stack. Its energy was determined from range and ionization measurements.
[b] The momentum and energy of the Be^7 were obtained from conservation of momentum. The range of the Be^7 is consistent with this energy.

Only these reactions simultaneously satisfied the following conditions: (a) the momentum of the reaction products must be conserved (for the above capture reaction the x, y, and z components of the momentum unbalance were 20 ± 17, 2 ± 17 and 38 ± 33 Mev/c); (b) prongs B_2 and C must be stable against charged particle emission that would give rise to observable prongs; (c) the binding energy of the Λ in the hyperfragment must be positive; and (d) the mass of the negative K particle, as obtained from energy conservation in reactions (1) and (2), must be the same as the mass of the positive K particle (966 m_e) within the errors of measurement. The prong identities along with their ranges, energies and momenta are given in Table I.

From the hyperfragment decay reaction (2) and the Λ hyperon decay

$$\Lambda\rightarrow H^1+\pi^-+Q_\Lambda, \qquad (3)$$

where $Q_\Lambda=36.9\pm0.2$,[3] the binding energy of the Λ in the $_\Lambda Li^7$ is calculated to be 4.4 ± 0.7 Mev.[4]

The mass of the negative K particle was found from Eqs. (1) and (2) to be 966.4 ± 5.0 electron masses.

If condition (d) above (that the mass of the negative K particle be the same as the positive K particle) be relaxed, then two more capture reactions are found which satisfy the first three conditions. Both require a neutron to balance residual momentum.

$$K^-+C^{12}\rightarrow\pi^-+{_\Lambda Li^7}+He^3+H^1+n+Q_3, \qquad (4)$$

$$K^-+O^{16}\rightarrow\pi^-+{_\Lambda Li^7}+Be^7+H^1+n+Q_4. \qquad (5)$$

The mass of the negative K particle, using Eq. (2) would be $1008.4\pm5.0\,m_e$ for reaction (4) and $1065\pm19\,m_e$ for reaction (5). These last two masses are not in agreement with other measurements of negative-K-particle masses.[5]

[3] Friedlander, Keefe, Menon, and Merlin, Phil. Mag. **45**, 533 (1954).

[4] It is possible for the Be^7 to be left in an excited state. The only known excited level that would result in a bound Λ is that at 0.4 Mev [F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **27**, 77 (1955)]. This excitation would reduce the Λ binding energy to 4.0 ± 0.7 Mev.

[5] J. Hornbostel and E. O. Salant, Phys. Rev. **98**, 339 (1955) obtained $(931\pm24)\ m_e$ by $H\rho$ and range method. Chupp, Goldhaber, Goldhaber, Iloff, and Webb reported $(\geq966\pm6)\ m_e$ and $(\geq935\pm5)\ m_e$ from captures on free protons (unpublished). Webb, Chupp, Goldhaber, Goldhaber obtained $(963\pm12)\ m_e$ from comparison to the τ-meson mass [Phys. Rev. **101**, 1212 (1956)].

TABLE II. Measurements from Event 71.

Track	Identity	Range (μ)	Energy (Mev)	Momentum (Mev/c)
F	$_\Lambda He^4$	97.2 ± 1.0	14.0 ± 0.2	330 ± 3
F_1	He^3	19.7 ± 1.0	4.43 ± 0.10	158 ± 2
F_2	p	70.7 ± 1.0	2.91 ± 0.10	74 ± 1
F_3	π^-	$13\,970\pm420$	28.1 ± 0.5	89 ± 1

It should be noted that the same hyperfragment, $_\Lambda Li^7$, is obtained from all three acceptable reactions. The only other example that has come to our attention of a lithium hyperfragment whose binding energy has been measured, is an event[6] that might be interpreted as a $_\Lambda He^4$ or a $_\Lambda Li^7\rightarrow Li^6+H^1+\pi^-$ with a B.E. (Λ in Li^7) $=8\pm4$ Mev.

EVENT 71

A photograph of Event 71 is shown in Fig. 2. This event is quite likely another example of the capture of a negative K particle in a light nucleus. Four charged particles and a π^- meson and a hyperfragment, $_\Lambda He^4$ (track F), left the K^- ending. The $_\Lambda He^4$ stopped and decayed into a π^- meson and particles F_1 and F_2 which were coplanar to 4 ± 5 degrees. Particles F_1 and F_2 were identified as a He^3 and a proton by momentum conservation. The decay reaction is then

$$_\Lambda He^4\rightarrow He^3+H^1+\pi^-+Q_5. \qquad (6)$$

The resulting momentum unbalance was 3 ± 2, 2 ± 3, and 11 ± 14 Mev/c in the x, y, and z directions respectively. Measurements on the tracks from the hyperfragment are given in Table II.

From Eqs. (3) and (6), the binding energy of the Λ in $_\Lambda He^4$ is found to be

$$\text{B.E.}(\Lambda \text{ in } {_\Lambda He^4})=Q_\Lambda-Q_5,$$

which gives a value of the binding energy of 1.5 ± 0.6. This value is in excellent agreement with the values appearing in the literature.[7] It is interesting to note that the momentum of the Λ in the $_\Lambda He^4$, as obtained from the sum of the momenta of the proton and the π^- meson is rather high for this case, namely, 158 Mev/c.

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[6] G. Crussard and D. Morellet, Compt. rend. **236**, 64 (1953).

[7] For a recent summary of values of the binding energies of Λ hyperons in nuclei, see Seeman, Shapiro, and Stiller, Phys. Rev. **100**, 1480 (1955).

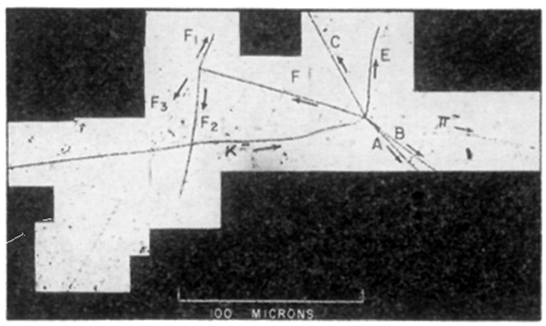

FIG. 2. A photomicrograph of the decay of a $_{\Lambda}He^4$ hyperfragment (track F) into a He^3 (F_1), a proton (F_2), and a π^- meson (F_3). The $_{\Lambda}He^4$ is emitted from the capture of a negative K particle, yielding, in addition to the hyperfragment, four charged particles (A, B, C, and E) and a π^- meson (Event 71).