Evidence of Neutrons in Heavy Particle Showers

Heitler[1] has calculated the cross section for the following reactions which should occur with a frequency that would permit detection.

$$h\nu + P \rightleftarrows Y^+ + N, \quad (1)$$

$$h\nu + N \rightleftarrows Y^- + P. \quad (2)$$

He also states heavy particle showers may be originated by processes similar to the following:

$$Y^+ + N = P + Y^+ + Y^-. \quad (3)$$

In the above, Y is a barytron, N a neutron, and P a proton, while h and ν have their usual significance. While the cross section computed for (1) and (2) only holds for energies of 10^8 ev, we thought it interesting to look for evidence of neutrons in heavy showers. The experimental work done at Denver is as follows: In Fig. 1A, a lead plate, 2 cm in thickness is placed 4 cm above counter 1. Counter 3 is shielded with 10 cm of lead. A block of paraffin alternately occupies positions A and B. With paraffin in position B, ionizing particles ejected from it by neutrons will not trip the counting mechanism; while when the paraffin is in position A, such liberated charged corpuscles may actuate the counting system. The ratio of counts per unit of time with paraffin in position A to those with paraffin in position B is 1.30 ± 0.06, where 0.06 is the probable error of the mean.

The second type of experiment was done with the apparatus shown in Fig. 1B. The three counters in triangular formation were completely surrounded by 10 cm of lead. Readings were taken with 3.4 cm of paraffin in the space above the counters, and with nothing in this space. The ratio of the number of showers per second detected through this system with paraffin to that with no paraffin is 1.27 ∓ 0.07.

In the third experiment the G-M telescope arrangement is illustrated in Fig. 1C. Here the 2 cm block of lead was left above the telescope and respective counts taken with the paraffin in positions A and B. The ratio of counts with paraffin in position A to those when it was between counters 1 and 2 is 1.08 ∓ 0.04.

The arrangement of G-M counters used at Macdonald College is shown in Fig. 2. The shaded areas represent lead and the portions marked P represent paraffin. In all cases, the lead scatterer above the system was of greater than the optimum thickness for shower production, so that the

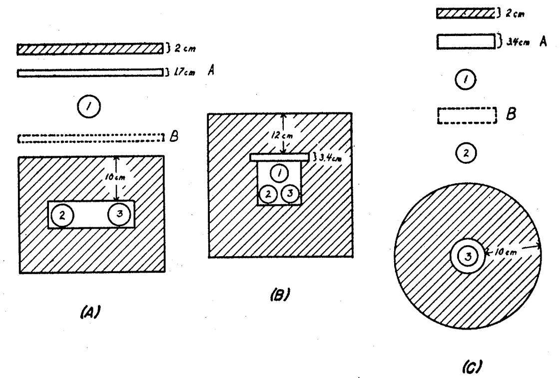

FIG. 1. Arrangements of counters with lead and paraffin absorbers at the University of Denver.

addition of a layer of paraffin to it should decrease the coincidence rate, especially since paraffin contains only very light elements. It was hoped that neutrons formed in the lead scatterer would eject protons from the paraffin to excite the counters. The results obtained up to the present with two sets of counters are given in Table I.

In agreement with Schein and Wilson[2] the ratio (3 : 4) does not differ significantly from unity near sea level. It appears from these results that, (i) the presence of a block of paraffin above a system of counters arranged so as to detect a minimum of one, two or three penetrating ionizing rays increases the counting rate; (ii) this effect is increased by the presence of a lead scatterer above the paraffin; (iii) any increase in counting rate due to the presence of a lead scatterer is magnified by a sheet of paraffin placed immediately below the lead; (iv) paraffin placed immediately above the lower counters in arrangements like b, Fig. 1, also shows an anomalously high absorption for the shower rays, exceeding even the absorption of the penetrating component of the cosmic rays in lead.

We believe that these results support the hypothesis that neutrons or neutrettos are produced in lead by nonionizing radiations. Probably the process is intimately associated with the production of the highly divergent penetrating showers. This would be in agreement with the cloud-chamber observations of Locher.[3]

The high absorption by paraffin may be due to excessive energy losses by the barytrons and protons of the shower in elastic collisions with hydrogen nuclei.

TABLE I. *Dependence of counting rates on the positions of the paraffin and the lead scatterers.*

Counter and absorber arrangement	Counts per hour	Ratio of Rates
1. a, lead at A, with P	36.6 ∓ 0.46	1 : 2, 1.045 ∓ 0.017
2. a, lead at B, with P	35.0 ∓ 0.37	3 : 4, 1.018 ∓ 0.010
3. a, lead at A, without P	33.6 ∓ 0.24	1 : 3, 1.09 ∓ 0.016
4. a, lead at B, without P	33.0 ∓ 0.23	2 : 4, 1.06 ∓ 0.013
5. b, lead at A, with P	1.17 ∓ 0.06	5 : 6, 1.15 ∓ 0.08
6. b, lead at B, with P counters	1.02 ∓ 0.05	7 : 8, 1.40 ∓ 0.09
7. b, lead at A, without P 1, 2, 3	1.35 ∓ 0.06	5 : 7, 0.87 ∓ 0.06
8. b, lead at B, without P	0.965 ∓ 0.05	6 : 8, 1.06 ∓ 0.06
9. b, lead at A, with P	0.176 ∓ 0.02	9 : 10, 1.16 ∓ 0.2
10. b, lead at B, with P counters 1, 2, 3, 4	0.151 ∓ 0.02	11 : 12, 1.08 ∓ 0.3
11. b, lead at A, without P	0.220 ∓ 0.02	9 : 11, 0.80 ∓ 0.12
12. b, lead at B, without P	0.203 ± 0.02	10 : 12, 0.75 ± 0.12

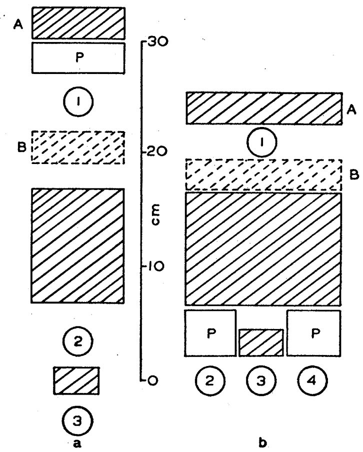

FIG. 2. Arrangements of counters with lead and paraffin absorbers at Macdonald College.

Experiments are being started which will determine how this ratio varies with (i) thickness of paraffin used, (ii) thickness of absorber above lower counter, (iii) thickness of lead scattering block. A more complete study of the apparently high absorption of penetrating cosmic rays by paraffin is also being initiated.

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Neutron Induced Radioactivity in Columbium

The neutron induced activity in columbium is so weak that it has been reported to be almost completely inactive.[1] According to the survey reported by Pool, Cork and Thornton,[2] two weak periods 7.3 minutes and 3.8 days were found. But neither a test for the sign of the β-rays emitted nor any attempt for the assignment were given yet.

A study of the activity produced in columbium has been made with the Tokyo cyclotron which gives a 3-Mev deuteron beam up to 50 microamperes in intensity.

The results obtained so far are given in Table I.

To test the activities due to some impurities, several runs were made on the special samples which had been purified with extreme care by one of the authors (M. I.) from columbium oxide powder of Kahlbaum.

The relative intensities of 7.5*m*, 66*h* and 11*d* were almost the same as those obtained in other samples. As for the 8*h* period, however, only a trace of its activity was noticed. This fact suggests that this period must be due to a tantalum impurity which is very hard to separate from columbium.

TABLE I. *Results on activity of columbium.*

Slow neutrons (Be+D paraffin)	*W* 7.5±0.5*m*	—	*VW* 66±10*h*	—
Fast neutrons (Li+D)	—	*VW* 8±2*h*	*W* 66±3*h*	*W* 11±1*d*
Sign of β-rays	e^-	e^-	e^-	e^-
Chemical test	—	Cb	Y	Cb
Assignment	Cb^{94}	Ta^{180}*	Y^{90}	Cb^{92}
Reaction	(n, γ)	$(n, 2n)$	(n, α)	$(n, 2n)$
Upper limit derived from K–U plot (Mev)	—	—	2.3±0.3	1±0.2

* Impurity (see reference 1).

The 7.5*m* period is in good agreement with Pool, Cork and Thornton. The 66*h* period is undoubtedly identical with the 3.8*d* period found by Pool and others. A correction made for the 11*d* is responsible for the difference. The K–U plot for this activity is in good agreement with that for Y^{90} produced from Y^{89}.

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Raman Effect of Dibromofluoromethane

We have observed nine Raman shifts of dibromofluoromethane using our three prism Steinheil spectrograph (dispersion 8A/mm at 4358A). Eight concentric neon-mercury lamps furnished the radiation. No filters were used. The sample was kept at about 40°C by means of an air blast. The results are shown in Table I.

Three types of photographic plates were used: Two Eastman Ortho-Press Plates (exposure 11.5 hours), one Eastman Spectroscopic Plate Type IG (exposure 41.5 hours) and one Eastman Spectroscopic Plate Type IJ (exposure 47 hours). Only on the type IG plate were the Raman lines excited by 5460A noticed and in this case