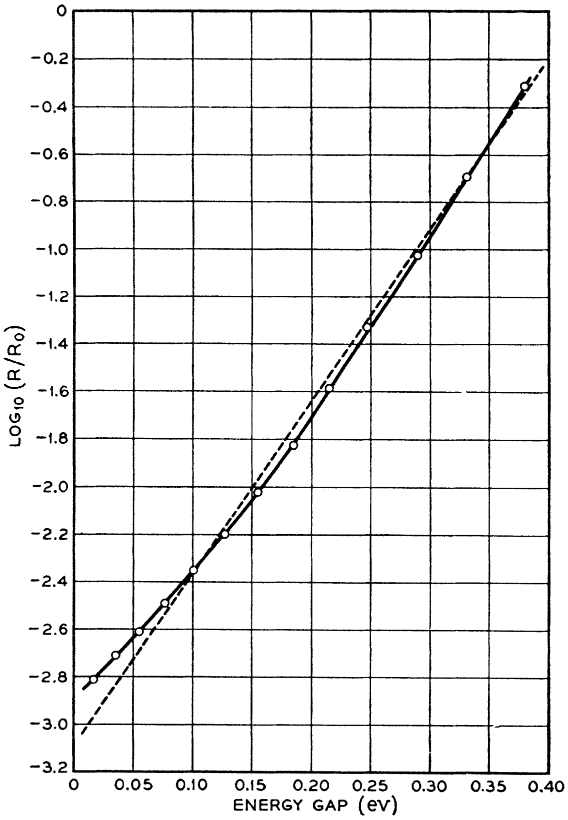

FIG. 2. Relative resistance of tellurium as a function of the energy gap. The dotted line gives the resistance change expected from the change in energy gap alone, other factors remaining constant with pressure.

As may be seen from Eq. (1), a decrease in E_G results in a decrease in R with pressure. When evaluated for $T=348°K$ (75°C), Eq. (1) may be written in the form

$$\log_{10}(R/R_0)=\log_{10}(R_\infty/R_0)+7.3E_G. \quad (4)$$

In Fig. 2 we have plotted $\log_{10}(R/R_0)$ from Bridgman's measurements as a function of E_G, using the extrapolated values of E_G at low pressures, and have shown for comparison a line of slope 7.3. It can be seen that the major cause of the pressure change of resistance is the decrease in the energy gap, E_G, and that changes in R_∞ with pressure are of secondary importance.

[1] P. W. Bridgman, Proc. Am. Acad. Sci. **72**, 159 (1938). Earlier measurements to 12,000 kg/cm² which cover a larger temperature range are given by the same author in Proc. Am. Acad. Sci. **68**, 95 (1933).
[2] V. E. Bottom, Phys. Rev. **74**, 1218(A) (1948), V. A. Johnson, Phys. Rev. **74**, 1255(A) (1948). Miss Johnson gives a value of 0.38 ev for the energy gap.
[3] P. W. Bridgman, Proc. Am. Acad. Sci. **74**, 21 (1940).

Gamma-Rays from Tantalum 182

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In an earlier investigation[1] it was found that pure tantalum oxide irradiated in the Oak Ridge pile formed the radioactive tantalum isotope of mass 182, which emitted a profusion of electron groups due to several internally converted gamma-rays. With the increased absolute accuracy and sensitivity now available with our photographic beta-spectrometers this emitter has been reexamined and found to yield several previously unobserved gamma-rays, all fitting into a logical decay scheme. In all, 48 electron lines are observed as shown collectively in column 1, Table I.

TABLE I. Electron energies with their identification.

Electron energy	Possible interpretation	Gamma-energy	Electron energy	Possible interpretation	Gamma-energy
30.2 kev	K_9	99.5	90.0 kev	M_8	92.8
34.1	L_1	46.2		or K_{18}	159.3
37.7	K_{10}	107.0	96.1	M_9	98.9
40.0	K_{11}	109.3	98.2	N_9	98.8
43.3	M_1	46.1	100.0	L_{12}	112.1
	or K_{12}	112.6	102.2	K_{19}	171.5
46.4	L_2	58.5	108.3	K_{20}	177.6
48.4	K_{13}	117.7	109.2	M_{12}	112.0
52.7	L_3	64.8	127.1	K_{21}	196.4
53.4	K_{14}	122.7	137.8	L_{16}	149.9
54.7	L_4	66.8	142.2	K_{22}	211.5
55.3	M_2	58.1	147.2	M_{16}	150.0
56.7	L_5	68.8		or L_{18}	159.3
61.7	M_3	64.5	150.4	K_{23}	219.7
64.1	N_3	64.7	157.7	K_{24}	227.0
	or M_4	66.9	165.3	L_{20}	177.4
	or L_6	76.2	174.2	M_{20}	177.0
66.1	M_5	68.9	176.8	N_{20}	177.4
	or N_4	66.7	184.7	L_{21}	196.8
69.1	K_{15}	138.4	191.3	K_{25}	260.6
71.5	L_7	83.6	208.6	L_{23}	220.7
73.2	M_6	76.0	215.6	L_{24}	227.7
81.2	M_7	84.0	216.7	M_{23}	219.5
	or L_8	93.3	224.0	M_{24}	226.8
	or K_{16}	150.5	232.3	K_{26}	301.6
87.1	L_9	99.2	237.9	K_{27}	307.2
88.6	K_{17}	157.9	250.3	L_{25}	262.4
			259.1	K_{28}	328.4

On applying the K–L–M differences characteristic of tungsten ($Z=74$) following beta-emission from tantalum ($Z=73$), the electron lines give evidence for the existence of 28 gamma-rays, as shown in column 3, Table I, and summarized in Table II. Some of the electron lines as shown in column 2 are subject to alternate or dual interpretation. The subscripts for the number of the gamma-ray are arbitrarily assigned in the order of increasing energy.

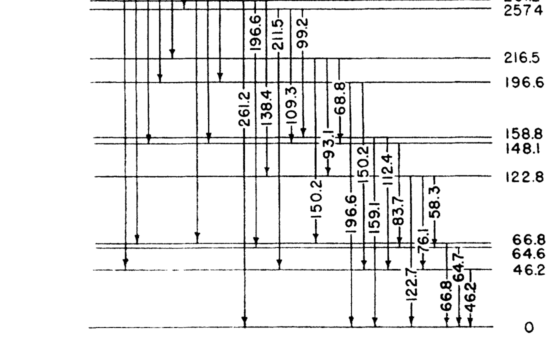

FIG. 1. Energy levels in tungsten 182 following beta-emission from tantalum.

TABLE II. Energy of gamma-rays.

Number	Gamma-energy	Number	Gamma-energy
1	46.2 kev	15	138.4
2	58.3	16	150.2
3	64.7	17	157.9
4	66.8	18	159.1
5	68.8	19	171.5
6	76.1	20	177.5
7	83.7	21	196.6
8	93.1	22	211.5
9	99.2	23	219.7
10	107.0	24	227.0
11	109.3	25	261.2
12	112.4	26	301.6
13	117.7	27	307.2
14	122.7	28	328.4

It can be noted that a great many numerical identities exist between mathematical combinations of the gamma-energies. For example, ten distinct combinations are observed to add to 374.5 kev. This suggests the possibility of a nuclear level scheme as shown in Fig. 1. While this proposal is undoubtedly not unique, it is remarkable that the 13 levels account completely for the 28 observed gamma-rays. In only a few cases do the gamma-energies deviate from the level differences by as much as 0.3 kev.

The decay of the tantalum shows the presence of activities of half-lives 3.5 days and 123.5 days. The radiations from the short-lived emitter have not been determined. This investigation was made possible by the support of the AEC and the ONR.

[1] J. M. Cork, Phys. Rev. 72, 581 (1947).

Nuclear Collisions of Heavy Cosmic-Ray Primaries

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April 13, 1949

HEAVY primary cosmic-ray ions, predicted by Alfven[1] and later discovered at high altitudes in photographic plates and cloud chambers,[2] are absorbed in the upper layer of the atmosphere mainly as a result of nuclear collisions. One may classify these collisions according to their effect on the bombarding nucleus as follows:

(a) The incoming nucleus can proceed almost undeflected with undiminished charge. In this case a few nucleons may be ejected from the target nucleus. An example of such a collision is given in Fig. 1.
(b) The incoming nucleus may be completely destroyed in a large nuclear explosion. An example of such an event was published earlier.[3]
(c) Part of the incoming nucleus may be sheared off in the collision. The remaining nuclear matter proceeds with its original momentum either as a compact nucleus of reduced charge or partially or completely dissociated. This type of collision results therefore in a *narrow penetrating shower* consisting in general of relativistic protons, α-particles and heavy fragments.

We have so far observed eight narrow showers of relativistic particles. Most of these were observed in a 3″×10″ stack of 25 electron sensitive Eastman NTB3 plates flown for 6 hours at an altitude of 92,000 ft. off the coast of Cuba ($\lambda=29\frac{1}{2}°$N magn.). In the three cases where the incoming nucleus belonged to the carbon, nitrogen, oxygen group the shower contains only protons or a mixture of α-particles and protons. An example of such a shower is shown in Fig. 2.

In the remaining five cases where the bombarding nuclei have charges $Z=14$, 19, 20, 26, and 26 the shower contained in each case one heavy fragment of charge $Z=10$, 11, 10, 10, and 20, respectively. One example is shown in Fig. 3. The picture shows two sections of the same track in two adjacent photographic plates. The collision occurred in the glass between the emulsions.

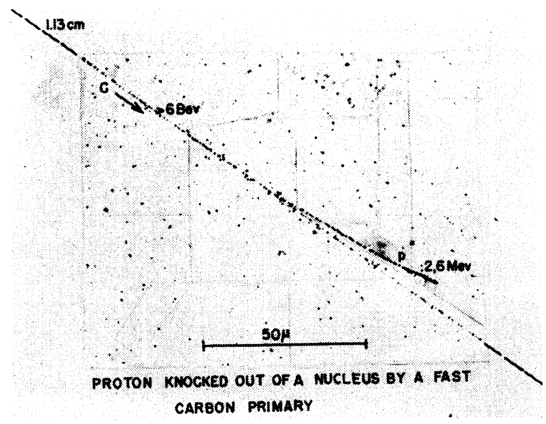

FIG. 1. Proton knocked out of a nucleus by a fast carbon primary (E_{kin} ~10 Bev). The track of the heavy ion in the emulsion was 1.13 cm long and the charge $Z=6$ was determined both by grain counting and δ-ray counting. The energy of the secondary proton is $E_p=2.6$ Mev and the angle between the track of the carbon ion and the proton track is $\vartheta=20°$ ($\vartheta_{\text{proj}}=5°$). Hence the collision could not have been an elastic collision (Ilford C-2 emulsion).

The frequency of these showers is comparable (though perhaps smaller) to the number of collisions leading to total destruction of the incoming particle. They have not been observed earlier because all the lighter shower particles being in the relativistic range will only be recorded in electron sensitive emulsions, such as the Eastman NTB3 plates.

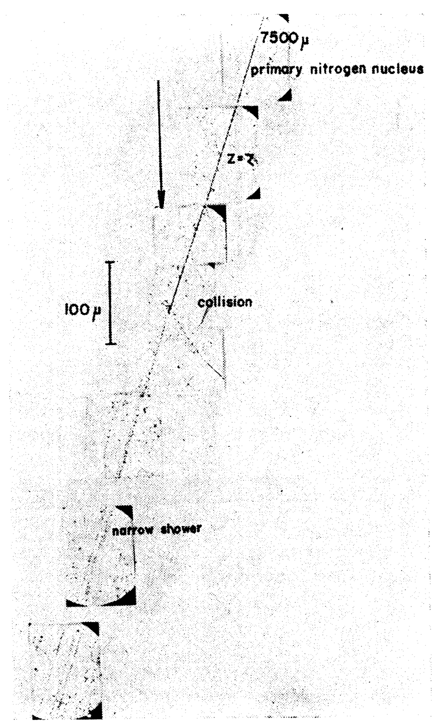

FIG. 2. Narrow shower of protons and α-particles resulting from the collision of a primary nitrogen nucleus. One of the α-particles has a path length of 5 cm in the emulsion. The projected angles between the tracks are 0.033, 0.077, and 0.110 degrees, respectively. (Eastman NTB3 emulsion.)