TABLE I.

λ	Classification	$\Delta\nu_{\text{calc.}}$ 10^{-3} cm^{-1}	$\Delta\nu_{\text{meas.}}$ 10^{-3} cm^{-1}	
5446·920	$\left\{\begin{matrix} a^5F_2-z^5D_2^0 \\ (a^3F_2-z^3D_3^0) \end{matrix}\right\}$	+160		very weak—not measured
5404·144	$\left\{\begin{matrix} z^3G_4^0-e^3H_5 \\ (z^5G_5^0-f^5G_5) \end{matrix}\right\}$	+120	+117	
4210·352	$z^7D_1^0-e^7D_1$		−226	
4466·554	$\left\{\begin{matrix} b^3P_2-x_3D_3^0 \\ (a^5D_1-z^7F_0^0) \end{matrix}\right\}$	−120	−77	
3684·108	$a^3G_4-v^3D_3^0$		−227	
3682·226	$a'D_2-w'D_3^0$		+245	
3605·450	$\left\{\begin{matrix} a^3G_4-y^3H_4^0 \\ (z^7F_6^0-f^7D_5) \end{matrix}\right\}$	−400	−368	
3383·692	$\left\{\begin{matrix} a^5P_2-w^3D_1^0 \\ (b^3G_5-9_4^0) \end{matrix}\right\}$	+140		very weak—not measured
3306·356	$\left\{\begin{matrix} a^5P_1-v^5P_2^0 \\ (a'G_4-w'G_4^0) \end{matrix}\right\}$	+50	132	same intensity
3239·436	$\left\{\begin{matrix} z^7D_4^0-f^5D_4 \\ (z^7D_1^0-f^5D_1) \end{matrix}\right\}$	−220	−224	
3214·044	$\left\{\begin{matrix} z^7D_3^0-e^7P_2 \\ (z^5F_4^0-g^5G_5) \\ (z^7D_3^0-f^7D_3) \end{matrix}\right\}$	+380 +530	+360 +490	
3199·530	$\left\{\begin{matrix} z^7D_4^0-f^7D_4 \\ (a^5D_1-z^3F_2^0) \end{matrix}\right\}$	+290	+302	
3125·653	$\left\{\begin{matrix} a^5F_2-x^5D_3^0 \\ (z^7D_5^0-e^7G_4) \end{matrix}\right\}$	−30	+297	
2970·106	$\left\{\begin{matrix} a^5D_1-y^5F_2^0 \\ a^5D_2-z^3P_1^0 \end{matrix}\right\}$	−210	−230	

The above results are in agreement with those reported recently[1] and similar to those concerning Ni 61.

A point which might be of interest that was noticed during the course of the research was the resolution of a few lines coinciding accidentally that have not been reported before. These lines are listed below with Russell's[2] classifications, the separations calculated from the term analysis, and the separations actually observed (see Table I). ($\Delta\nu>0$ means that the weak component has a higher frequency than the strong component from which it is measured.)

There is agreement with the Zeeman effect data of D. W. Weeks.[2]

The sample of Fe 57, enriched to 68 percent, was provided by the AEC.

* Assisted by the joint program of the ONR and the AEC.

[1] M. Gurevitch and J. G. Teasdale, Phys. Rev. **76**, 151 (1949).

[2] Russell, Moore, and Weeks, Trans. Am. Phil. Soc. **34**(II) (December 1944).

Energetic Events in Emulsions at High Altitude*

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IN Eastman NTB3 emulsions, exposed with planes vertical at 93,000 feet for 6 hours near Cuba (31° geomagnetic north; vertical cut-off 8 Bev[1]), many stars show straight, light tracks of minimum and near-minimum grain density, in addition, of course, to the heavy prongs visible in ordinary, less sensitive emulsions. While the light tracks can be safely ascribed to fast particles, of relativistic and near-relativistic kinetic energies, and are thought due at least in part to mesons, the portions of tracks within the emulsions are too short to decide from their appearance whether the particles are electrons, mesons or protons. Near-minimum grain densities refer to kinetic energies between 0.2 and 0.6 rest energy.

Out of 124 stars with light tracks, 76 showed, in the hemisphere above the star, a minimum ionization track, which is taken to be that of the incoming particle initiating the disintegration, either a primary proton or, in possibly a third of the events, a secondary of comparable energy, ejected from the thin (15 g/cm²) atmosphere above the plates.

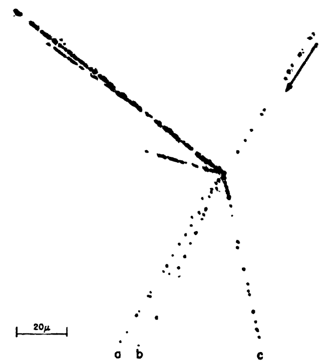

FIG. 1. Disintegration with 4 minimum ionization tracks within 43° and 4 heavy prongs. Between *a* and *b* are 3 min.-ion tracks within 20°, one dipping out of focus. Fourth track *c* is within 43° of *a*. Background removed.

Figures 1 and 2 are microphotographs of stars with some characteristic features of the light tracks (arrow indicates track of incident particle). Selecting the 47 events with 4 or more light tracks, 35 of them show 3 or more light tracks fanning out downward, roughly in the direction of the incident particle, giving the appearance of a broom. But in 10 of the broom, the handle, i.e., the incident particle, is missing, and while a few misses could arise from possible closeness to the inconvenient normal to the plate, the rest are attributable to non-ionizing radiation, presumably energetic neutrons. In the remaining 12 events, the fast particles appear uncollimated.

Outgoing light tracks in these brooms number 6 on the average, extending up to 12, and 120 of the 210 tracks have minimum ionization, the angles of near-minimum tracks being widely and rather uniformly spaced. In 27 of the brooms, there are usually 3 or 4, sometimes as many as 9, minimum ionization tracks, contained within a narrower broom, with angular spread generally between 50° and 100°. In 8 of these events, about the same number of minimum ionization tracks are in a still narrower core, of less than 20° spread. Thus it appears that the relativistic particles are more closely collimated than the near-relativistic and their angular spreads tend to fall into two groups. There is also evidence, though not yet statistically sound, for some fast particles to be created in pairs, within a few degrees of each other.

Considering, now, the stars' heavy prongs (uncollimated), 70 out of 90 of those stars with enough heavy prongs to be assigned to disintegrations of the heavy nuclei Ag, Br and I show emission of relativistic or near-relativistic particles. Very energetic stars, with up to 36 heavy prongs and 7 light tracks are observed. Even with an average of 35 Mev per prong found by Harding, Lattimore and Perkins[2] (likely to be higher at our latitude and altitude), over

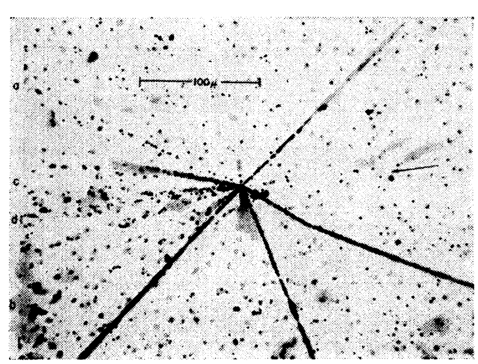

FIG. 2. Disintegration with 12 heavy prongs, 12 min. and near-min. tracks within 100°. Between *a* and *b*, 52° apart, are 8, and between *c* and *d*, 10° apart, are 5 minimum ionization tracks.

3 Bev of energy is dissipated in one such large star, if the light tracks are mesons and not electrons, and more if they are protons.

Comparing Ilford C2 emulsions on this and on a similar flight at 57° geomagnetic north (vertical cut-off 2.8 Bev),[1] production-rates of stars of 5 or more prongs was found greater by a factor of 3.6 ± 0.4 at the northern latitude; this figure includes production during ascent and descent but not at sea-level.

We take great pleasure in acknowledging our gratitude to the Office of Naval Research for putting the balloon flight at our disposal, and to the officers and men of the USS Saipan and Mr. S. E. Golian of this laboratory, who were responsible for the success of this flight.

* Research carried out at the Brookhaven National Laboratory under the auspices of the AEC.

[1] M. S. Vallarta, Phys. Rev. **74**, 1837 (1948).
[2] Harding, Lattimore, and Perkins, Proc. Roy. Soc. A **196**, 325 (1949)

Conductivity Changes in Dielectrics during 2.5-Mev X-Radiation

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PRELIMINARY measurements of volume conductivity have been made on three plastic dielectrics during irradiation by 2.5-Mev x-rays.

To measure the volume conductivity, a potential difference was applied across the sample and the resultant current was measured with an FP54 electrometer tube and Penick-type bridge circuit.[1] The sample, the electrometer tube, and the control grid leads were in a vacuum at 1 micron pressure in order to reduce parallel path ion current leakages and to establish easily reproducible pressure and humidity conditions at the sample.

Figure 1 shows the data taken on a sample of Okoseal, polyvinyl chloride manufactured by the Okonite Company. The conductivity of this material was found to increase very rapidly upon the start of irradiation and quickly reached an equilibrium value which was dependent on irradiation rate. This value was approximately thirty times the original conductivity at an irradiation rate of about 400 R/min. Upon stopping the irradiation, the recovery was half complete in thirty minutes, nine-tenths complete in sixteen hours.

A sample of Saran, vinylidene chloride manufactured by Dow Chemical Company, showed somewhat different characteristics. The conductivity increased slowly over a period of about two hours (2.7×10^5 R total irradiation at 2000 R/min.) until it was about three times the original conductivity. At this point the irradiation was stopped because of apparatus difficulty. The initial recovery rate was much lower than for Okoseal. After eighty-two hours recovery was complete to within the precision of measurement.

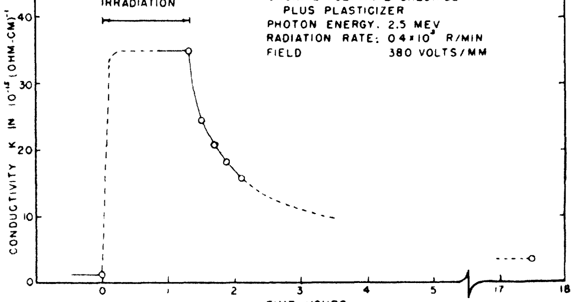

FIG. 1. Conductivity of Okoseal showing effect of irradiation.

A preliminary measurement on a sample of polystyrene showed that after a total irradiation of 5500 R at 1000 R/min., the conductivity had not risen to as much as 2×10^{-17} (ohm-cm)$^{-1}$. Assuming an initial conductivity of 10^{-20} (ohm-cm)$^{-1}$, the change was by less than a factor of 2×10^3. This result is in contrast to the report by Farmer[2] of a change by a factor of approximately 10^7 after a total irradiation of only 4000 R.

The fact that the dielectrics become conducting during irradiation is to be expected by a mechanism such as that described by Mott and Gurney,[3] whereby the passage of primary current (due directly to absorbed photons) changes the dielectric in such a way as to reduce the electrical barrier at the electrode-dielectric interface. However, the extent of change and the time constants are not readily predictable, and these measurements show that a considerable spread in the magnitude of these factors is to be expected among the various plastic dielectrics.

The authors are grateful to Professor J. G. Trump and his associates, particularly the late Mr. A. M. Clarke and Mr. K. A. Wright, for use of the x-ray generator and for their cooperation in the experiments.

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[1] D. B. Penick, Rev. Sci. Inst. **6**, 115 (1935).
[2] F. T. Farmer, Nature **150**, 521 (1942).
[3] Mott and Gurney, *Electronic Processes in Ionic Crystals* (Clarendon Press, Oxford, 1940), pp. 185–188.

Heavy Particles in Cosmic-Ray Stars*

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IN scanning nuclear emulsions exposed for three hours at an altitude of 93,000 ft. in Minnesota ($\lambda=55°$N) the authors have observed stars with heavy particles. Although we have obtained as yet no statistics on the relative frequency of their occurrence, we have observed at least 6 stars with heavy particles ($Z\geqq3$) originating in stars both in vertical plates with no absorber and in horizontal plates under Pb (11.3 g/cm^2) and Cu (11.2 g/cm^2) absorber. We believe these to be secondary particles of the kind previously reported by Bonetti and Dilworth[1] and by Hodgson and Perkins.[2]

The star with three heavy particles shown in Fig. 1 is interesting in connection with publications on stars produced by heavy particles[3–5] and stars in which heavy particles are emitted. The three tracks A, B and C have δ-rays and are ascribed to particles with $Z\geqq3$. This star was found in a 70μ Eastman Kodak NTB emulsion impregnated with Bi in colloidal form.[6] The plate was exposed in vertical position without absorber. The orientation of the star in the emulsion is indicated by the arrow pointing to the zenith. Tracks A and B are collinear within the accuracy of our measurements and track C is inclined at about 30° to the direction of B. The track D of a light energetic particle lies almost parallel to B. Extensions of the tracks A and C were found on the adjacent identical plate but none of the tracks ends in the emulsion.

From the point of view of orientation A is the only one of the heavy particles which can be incoming. At first glance, therefore, the star of Fig. 1 resembles one of the type described by Bradt and Peters[5] where part of the incoming nucleon is sheared off in the collision and the remainder continues with the original momentum as a compact nucleus of reduced charge. However, the presence of the heavy particle C at a large angle (30°) to direction of A, with $Z\cong5$ and with a minimum energy of 220 Mev indicates that the event of Fig. 1 is different. Particles B and C cannot be primary particles as can be seen from the orientation of the stars. Careful δ-ray counts made independently by two observers show that A cannot be a primary particle but must be leaving the disintegrating nucleus. Although particle A does not end in the emul-

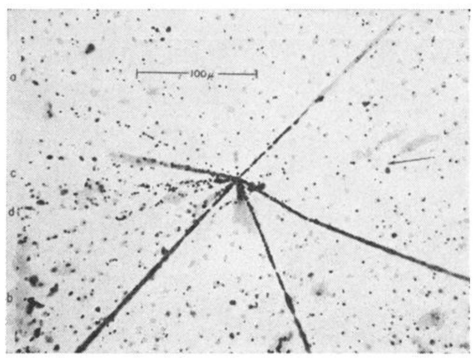

FIG. 2. Disintegration with 12 heavy prongs, 12 min. and near-min. tracks within 100°. Between *a* and *b*, 52° apart, are 8, and between *c* and *d*, 10° apart, are 5 minimum ionization tracks.