Detection of Nuclear Disintegration Products

Since it appears that the field of research embracing nuclear disintegrations and other results of bombardment by fast heavy particles will be a wide one, the authors have been developing a method for high voltage bombardment suitable for use even in laboratories where space and funds are limited. The method was reported[1] briefly before the American Physical Society eighteen months ago and consists in constructing a belt type electrostatic generator in an enclosure maintained at a high air pressure to increase the breakdown strength of the medium and so permit maintenance of high voltages on an apparatus of small dimensions. A complete description will be published in the near future. One problem met has led to a solution of interest to others engaged in nuclear research and is here reported.

In a small apparatus, the high potential element is necessarily small and cannot contain within itself much auxiliary equipment. Yet in any practical experiment it must contain either a generating source for bombarding particles or a device capable of detecting results of nuclear bombardment. With sources known at present, the decision is forced. A source drawing bombarding particles from a gas discharge requires batteries, rheostats, etc., of some bulk. Also gas leaking from such a source into the main accelerating tube through the canal provided for the projectile particles is most efficiently removed by fast pumps connected to the tube at a point near the source. Such a fast pumping system cannot be built in restricted space. At first sight, it appears equally hopeless to construct a sensitive detecting device in a small volume. Those heretofore used mainly are ionization chambers operated with electrometers or amplifiers, counting chambers or expansion cloud chambers, all of which employ extensive operating circuits or machinery.

Another method, relatively unexplored as yet, appeared well adapted for our purpose, namely, the technique of observing the tracks of alpha- or other disintegration-particles which have passed into photographic emulsions.[2] A permanent record is made through development of individual grains along the tracks of the particles, the traces appearing through a microscope not unlike a negative photograph of a cloud-chamber track. A piece of target material, suitable screens and a small photographic plate require very little space indeed.

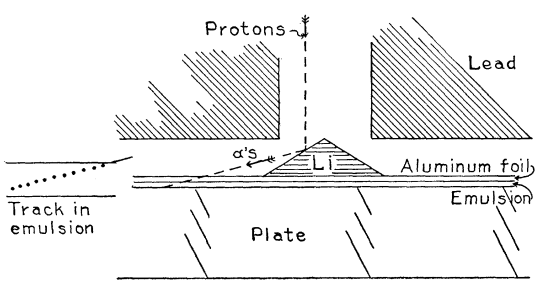

FIG. 1. Arrangement of target, screens and plate.

FIG. 2. Micro-photograph of track in emulsion.

We have tested the application of the technique by bombarding lithium metal with 150 kv protons. While our work was in progress we were further encouraged by M. Blau's[3] success in recording the groups of disintegration protons ejected from aluminum when bombarded by polonium alpha-particles. It is a further step to use the method with artificially accelerated particles because incidental x-rays from the accelerating tube tend to fog the plate. After considerable trouble from this effect we have succeeded in detecting alpha-particles from artificially disintegrated lithium and are convinced that the compactness and simplicity of a photographic plate, added to the facts that it should be 100 percent sensitive, has no inoperable periods and automatically produces a permanent record, make this technique a very promising one.

We have used the arrangement of Fig. 1 employing Eastman Lantern Slide Plates, Slow, and developing with Eastman Kodac formula D-11. X-rays coming with the protons through the hole in the lead screen pass in part through the lithium and the aluminum foil provided to stop the protons and produce a blackening where they fall on the photographic plate. Soft x-rays generated by the impact of the protons on the lithium target do not penetrate the aluminum foil in sufficient strength to blacken the outer portions of the plate appreciably. Alpha-particles from the surface of the lithium pass as shown into the region shadowed by the lead and enter the emulsion at an angle, as indicated by an enlarged portion of the figure. After the plate is developed, the tracks confirm their own identity by the angle of penetration and by their general direction away from the x-ray spot on the plate. Fig. 2 shows such a track. It is a micro-photograph of a small portion of the plate. The track is in the center, nearly vertical in the photograph and consists of ten or eleven grains. Reading up, the first two or three grains are out of focus because they are too high in the emulsion for the microscope adjustment. The last grains are evidently more and more out of focus because they are successively deeper in the emulsion. The linearity of the

[1] Phys. Rev. **42**, 901A (1932).
[2] O. Mügge, Zentralbl. f. Mineralogie **71**, 147 (1909).
[3] M. Blau, J. de Phys. et le Rad. (VII) **5**, 49 (1934).

track can be observed and the angle of penetration measured by visually focussing the microscope on one grain after another.

We are at present improving our technique and testing the method by application to other problems of current interest. The work has been made possible through the generosity of the Department of Physics at Princeton University which provided all the equipment and supplies required. We are also greatly indebted to Professor R. Ladenburg and others of the staff for their advice and suggestions as well as to Professor T. R. Wilkins and Mr. W. T. Rayton of the University of Rochester who gave us valuable information about the emulsion technique.

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The Emission of Disintegration-Particles from Targets Bombarded by Protons and by Deuterium Ions at 1200 Kilovolts

In view of the hypothesis of the instability of the deuton with a resulting neutron-mass of nearly unity advanced[1] and supported[6, 7, 8] by Professor Lawrence and his colleagues at Berkeley, it appeared essential to us on beginning our own program of disintegration-observations in the region above 1000 kilovolts to check first their published results. Avoiding the introduction of lithium or boron into our new tube,[2] we selected the following as representative of the targets which they used: Be, C, SiO_2, CaF_2, Al and Ag (Pt was displaced by an Ag-target previously tested for contamination[2]). Observations have been made at 1200 kilovolts since last November on these six targets by using magnetically resolved mass-1 and mass-2 beams giving proton-currents of 1 to 2 microamperes and deuton-currents of 0.2 to 0.5 microampere. Voltage-measurements were made by range-measurements on the proton- and deutron-beams, checked at first by magnetic deflection-measurements. (A generating voltmeter was found to indicate too high a voltage by more than 50 percent, probably because of corona and space-charge, and was discarded as unreliable for use with the corona-limited electrostatic generator.) The ionization-chamber of the linear amplifier used in these experiments subtended a solid angle 1/200 to 1/700 of 4π, and the residual count (with the tube operating) was usually 1 to 3 counts per minute. Within the limits by which our targets overlap the published Berkeley data, we have obtained the following results.

(A) With 2 microamperes of protons on these targets no alpha-particle emission in significant numbers of range exceeding that of the primary protons was observed[3, 4, 5] except from CaF_2, which emits only one group[3] of range 60 mm, with no trace of any longer range alpha-particles. An unsuccessful search down to 2.2 cm was made for the 3.3-cm group reported for Be,[4] reducing the voltage in successive observations to eliminate possible spurious counts due to unresolved multiples of scattered primary protons giving deflections the same size as alpha-particles. With deutons, a strong alpha-particle group was found from CaF_2 ending near 71 mm.[3] Bombarding Be no evidence of the 3.3-cm group[5, 8] was found, although with deutons on Be the presence of neutron-recoils and disintegration-protons gives a rather high residual count. No other definite alpha-particle emission from these targets was observed by using deutons. Multiple-proton counts are indistinguishable from alpha-particles with an amplifier having fixed constants, and at short ranges spurious counts of this type were present with most of these targets under deuton-bombardment, thus preventing the identification of small numbers of alpha-particles if such were present.

(B) We have been unable to confirm the Berkeley reports[5, 6, 7] of an 18-cm group of protons from all targets, with similar reported yields[6] for targets as different in atomic number as "brass-wax" and platinum, using 1200-kilovolt deutons. A proton-group was found which showed the typical characteristics of a contamination-effect and which probably corresponds to their 18-cm group. Instead of the homogeneous group indicated by their hypothesis (but not by their observations[7]), this group showed an apparently continuous range-distribution, tapering out and disappearing between 15 and 17 cm, the end-point (as few as 1/10,000 of the maximum number of counts) being a function of the intensity of the group, whether changed by altering the current to one target or by shifting between targets. The quantitative yields from our targets differed by large factors from their yields, and varied greatly from target to target. The group was not observable from the Be-target (which did emit a group of longer range). The yield from the Ag-target was at most a small fraction of 1 percent of that from C, and the yield-ratios between various targets fluctuated from time to time, indicating at least some degree of transient contamination. Several other proton-groups were evidently characteristic of particular targets, but these have not been confirmed as yet by the necessary tests on several duplicate targets. The degree of caution necessary for such conclusions was sufficiently illustrated by our work with protons reported a year ago.[2] As described below, we have recently demon-

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3 E. O. Lawrence and M. S. Livingston, Phys. Rev. **44**, 316–317 (1933).

4 M. S. Livingston, M. C. Henderson and E. O. Lawrence, Phys. Rev. **44**, 316 (1933).

5 G. N. Lewis, M. S. Livingston and E. O. Lawrence, Phys. Rev. **44**, 55–56 (1933); **44**, 317 (1933).

6 M. S. Livingston, M. C. Henderson and E. O. Lawrence, Phys. Rev. **44**, 781–782 (1933).

7 G. N. Lewis, M. S. Livingston, M. C. Henderson and E. O. Lawrence, Phys. Rev. **45**, 242–244 (1934); **45**, 497 (1934).

8 E. O. Lawrence and M. S. Livingston, Phys. Rev. **45**, 220 (1934).

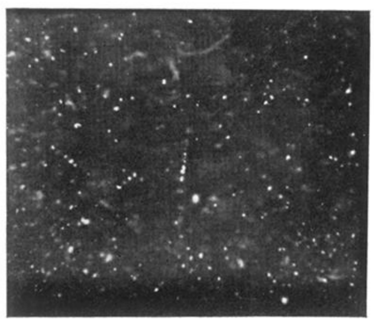

Fig. 2. Micro-photograph of track in emulsion.