Ionization of Air by Alpha- and Beta-Rays as a Function of Pressure

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(Received July 14, 1934)

Measurements of ionization of air by alpha-particles from polonium and by beta-rays excited by gamma-rays, were made under usual laboratory conditions. The ionization by beta-rays increased at a decreasing rate with increase in pressure, in accordance with results obtained in previous investigations. The ionization by alpha-particles decreased with increasing pressure, at first rapidly, then more slowly until, at 80 atmospheres, the value was approximately 5 percent of that at atmospheric pressure.

THE recent use of high pressure ionization chambers for measuring x-rays, gamma-rays and cosmic rays has raised anew the problem of ionization as a function of pressure. Many studies of ionization at pressures less than one atmosphere have been made.[1] At higher pressures, Erikson[2] performed pioneer experiments, using ionization by gamma-rays and working to pressures as great as 400 atmospheres. But with alpha-ray ionization almost no work seems to have been done until recent years.[3, 4, 5] The experiments of Erikson[2] and those of more recent investigators[4, 6, 7, 8, 9, 10] have shown that in air the ionization produced by beta-rays excited by gamma-rays is not proportional to the pressure but seems to approach a maximum at about 200 atmospheres and then decreases. With alpha-rays, it has long been known[1] that it is difficult to obtain a saturation ionization current, even at atmospheric pressure. Experiments by Steinke and Schindler[4] and Jacobsen and Madsen[5] have shown that at higher pressures the ionization by alpha-particles decreases to a small fraction of that at one atmosphere. Some discussion of the theory of these effects has been given by Rutherford,[1] Compton, Bennett and Stearns,[6] Bowen[8] and others.

For routine laboratory purposes, it was desirable to investigate, under usual laboratory conditions and with the same apparatus, the relationship of ionization of air by alpha-particles to that by beta-rays as a function of pressure. One occasion for making this comparison was the desire to learn how the residual radiation from the walls of an ionization chamber behaves as a function of pressure, the residual ionization being due to a mixture of alpha-, beta- and gamma-rays from radioactive impurities in the walls.

The apparatus used is a modification of that constructed and used by Bennett, Stearns and Compton[11] for the study of cosmic rays. It is shown diagrammatically in Fig. 1. The sources of ionization were: (*a*) beta-rays excited by gamma-rays; and (*b*) alpha-particles from polonium. The polonium was deposited electrolytically on a strip of platinum which was then placed at or near the center of the ionization chamber and about 2 millimeters from the electrode. A Lindemann electrometer, with sensitivity adjusted to 15 scale divisions per volt, was used to measure the ionization current. Two calibrated pressure gauges were used, one for pressures up to about 400 pounds per square inch, the other for higher pressures. The apparatus was left unshielded.

Beta-ray ionization at a given pressure was calculated as the difference between the value of the ionization current with the radium placed 1 meter from the electrode, then at infinity. In the latter case, the current was due to the effect of cosmic rays and local radiation. Alpha-ray

[1] Cf., e.g., E. Rutherford, *Radioactive Substances and their Radiations*, pp. 31–35 (1912).
[2] H. A. Erikson, Phys. Rev. **27**, 473 (1908).
[3] A. J. Dempster, Phys. Rev. **34**, 53 (1912).
[4] E. G. Steinke and H. Schindler, Naturwiss. **20**, 15 (1932).
[5] J. C. Jacobsen and C. B. Madsen, Naturwiss. **21**, 350 (1933).
[6] A. H. Compton, R. D. Bennett and J. C. Stearns, Phys. Rev. **39**, 873 (1932).
[7] R. A. Millikan and I. S. Bowen, Nature **128**, 582 (1932).
[8] I. S. Bowen, Phys. Rev. **41**, 24 (1932).
[9] J. W. Broxon, Phys. Rev. **42**, 321 (1932).
[10] J. J. Hopfield, Phys. Rev. **43**, 675 (1933).
[11] R. D. Bennett, J. C. Stearns and A. H. Compton, Phys. Rev. **41**, 119 (1932).

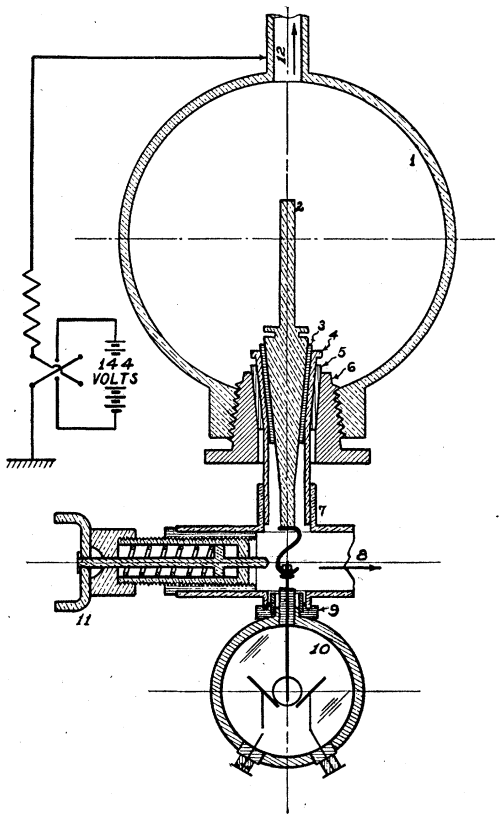

FIG. 1. Diagram of apparatus. 1, ionization chamber; 2, electrode; 3, amber cone; 4, brass cone; 5, rubber cone; 6, iron plug; 7, housing; 8, drying tube; 9, sponge rubber; 10, electrometer; 11, key; 12, inlet and gauges.

ionization was determined by measuring the difference in the values of the ordinates of two curves, the data for which were taken with, then without, polonium, respectively. In this manner the combined effect of cosmic rays, local radiation and contamination was eliminated. The data for beta-ray and alpha-ray ionization, calculated as indicated, are represented by Curve 1 and Curve 2, respectively, in Fig. 2. Curve 3 in Fig. 2 represents the ionization due to cosmic rays plus local radiation. The data for Curve 3 are multiplied by a factor of 10.

In general agreement with other investigations, the data show that, beginning at atmospheric

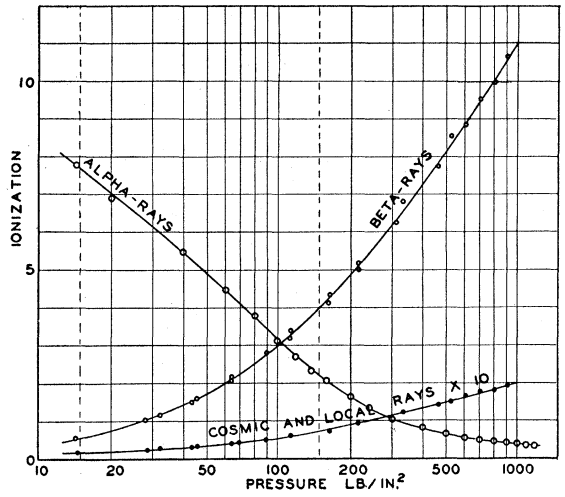

FIG. 2. Variation with pressure of the ionization due to alpha- and beta-rays.

pressure, ionization by beta-rays excited by gamma-rays increased at a diminishing rate with increase in pressure up to 60 atmospheres. On the other hand, ionization by alpha-particles from polonium, beginning at atmospheric pressure, at first decreased[4, 5] rapidly with increase in pressure, then more slowly until, at 80 atmospheres, about 5 percent of the initial value was reached. Saturation for the alpha-ray ionization was not attained.

These results indicate that in high pressure ionization chambers the wall effects due to alpha-rays are strongly though not completely suppressed relative to gamma-ray ionization. The relative importance of the beta-ray ionization from the walls is, on the other hand, not reduced by so great a factor as the pressure increases.

It is of interest to note that the form of the ionization-pressure curve for cosmic rays is similar to the beta-ray curve rather than to the alpha-ray curve. This supports the evidence from Wilson photographs that cosmic-ray ionization is due to particles of such high speed that the concentration of ions along their path is not high.

The writer wishes to thank Professor A. H. Compton for his suggestions in carrying out these experiments.