Positronium

ARTHUR E. RUARK*
*Naval Research Laboratory, Office of Research and Inventions, Anacostia, D. C.***
November 13, 1945

1. IN 1937 I conceived the idea that an unstable atom composed of a positron and a negative electron may exist in quantities sufficient for spectroscopic detection. The name *positronium* is suggested. The spectrum of positronium would have lines at wave-lengths twice as great as the hydrogen lines. The first line of the Lyman series would lie at 2430A and the Balmer series would run as follows: 13126A, 9722A, 8680A, and so on, to the limit at 7290A. It is possible that cosmic-ray positrons passing through great thicknesses of nebulous matter might excite this spectrum. A brief survey showed the paucity of our knowledge of the infra-red spectra of planetary nebulae. No indication of the lines was obtained. It was keenly realized that the great probability for annihilation of the atom would reduce the probability of detecting it in this way. The life of a positron in lead is about 10^{-10} sec. The life of the lower levels of free positronium should be greater. Thus the probability of a fall from one discrete energy state to another may be about 0.05 to 0.1 of the annihilation probability. For these reasons nothing was published. Now the situation has altered. Strong beams of positrons are available to workers with the betatron and this note is intended to call the subject to their attention.

2. Some interesting properties of positronium will be listed. Neglecting the effect of annihilation for the instant, we note that the Bohr radius is twice that for hydrogen. The approximate wave functions will be those of hydrogen, with the Bohr radius doubled. Finer details can be treated by the theories of Breit or of Möller. Some of the results of a complete calculation can be foreseen. In discussing hydrogen, the magnetic moment of the proton is neglected because its influence on the spectrum is so small. In discussing the fine structure of positronium, the spins of both particles must be considered; there will be both singlet and triplet states. Also a correction due to Darwin[1] must be included. However, all the states will be broadened by the large annihilation probability. It appears likely that this effect will obscure the fine structure. None of the discrete states are excluded by Pauli's principle.

3. The type of experiment required in a search for the line spectrum of this material consists in passing an intense beam of positrons into a gas of low atomic number, preferably helium. To increase the spectral intensity, high pressure should be employed. If the absolute intensity can be made sufficient, the question remains whether continuous spectra from the gas atoms will be more intense than the radiations sought for. The radiation of atoms which pick up a slow positron must also be considered. In another type of experiment, the modified spectrum produced by a liquid or solid could be examined; Cerenkov radiation would introduce a complication.

I think no physicist will doubt the existence of these unstable hydrogen-like atoms. Direct detection may prove difficult, but the great interest of such observations requires no emphasis.

4. Since writing the above, Professor John A. Wheeler has told me that he has submitted a paper for publication by the New York Academy of Sciences, entitled "Electromesons; Short Lived Entities Composed of Electrons and Positrons," which deals with questions like those discussed in this note. It has been a pleasure to learn of his ideas, which cover possibilities much broader than the simple case of a single electron and a single positron.

* On leave from the University of North Carolina, Chapel Hill, North Carolina.
** Published by permission of the Secretary of the Navy. The views expressed are not to be interpreted as the official views of the Navy.
[1] C. G. Darwin, Phil. Mag. **39**, 537 (1920); see brief account in Ruark and Urey, *Atoms, Molecules and Quanta*, p. 167.

Calibration of Ionization Gauge for Different Gases

S. DUSHMAN AND A. H. YOUNG
Research Laboratory, General Electric Company, Schenectady, New York
November 23, 1945

DURING the past few months we have attempted to calibrate ionization gages for a number of different gases. Table I shows calibration data for two FP-62 tubes and a VG-1 tube. In all cases the measurements were made with i_e (electron current) varying from 0.5 to 5 ma, and collector potential of -22 volt. The anode potential was 125 volts in the case of the FP tubes and 150 volts in that of the VG-1.

Denoting the pressure in microns by P, and the positive ion and electron currents by i_p and i_e, respectively, $s=i_p/(i_eP)$ and r denotes the ratio of s for the gas to that for argon. As will be observed the values of r for different gases appear to be independent to a large extent of the type

TABLE I. Calibration of ionization gauges with argon as a reference gas.

	FP-62(1)		FP-62(2)		VG-1		Av. value	
Gas	$s\times10^3$	r	$s\times10^3$	r	$s\times10^{-3}$	r	r	$r(P_i)$
He	0.77	0.140	0.70	0.133	2.88	0.127	0.133	0.14
Ne	1.08	0.196	1.08	0.205	4.65	0.206	0.202	0.21
A	5.50	1.0	5.27	1.0	22.6	1.0	1.0	1.00
Kr	8.9	1.62	8.4	1.59	32.9	1.46	1.56	—
Xe	12.0	2.16	13.0	2.46	50.9	2.25	2.29	—
Hg	15.0	2.73	14.5	2.75	72.0	3.18	2.89	1.90
H_2	2.14	0.39	2.10	0.40	8.65	0.38	0.39	0.34
N_2	4.90	0.89	4.40	0.83	18.2	0.81	0.84	0.90

of gauge used. The average values of r are in reasonably good agreement with relative values of the ionization probabilities at 100 volts as obtained by I. Langmuir and H. A. Jones.[1] These are shown in the last column of the table under $r(P_i)$.

It is interesting to note that in the case of the rare gases a plot of log r *versus* the ionization potentials deviates only slightly from a straight line.

A more detailed account of the measurements will be published in the near future.

[1] I. Langmuir and H. A. Jones, Phys. Rev. **31**, 357 (1928).