The behavior of the paramagnetic resonance spectra of these alums at low temperatures is similar to that observed in the optical spectra by Kraus and Nutting,[12] especially in the "shattering" of the ammonium alum, and the gradual transition in intensity from the high to the low temperature spectrum in the potassium alum. It may be that x-ray analysis will reveal structural differences such as those found in the aluminum alums[13] which can be correlated with the magnetic behavior. A further unexplained peculiarity of the alums is the Debye-type electrical relaxation discovered by Guillien.[14] Unfortunately his measurements do not cover a sufficient number of alums to detect correlatable differences in behavior.

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Microwave Magnetic Resonance Absorption in Oxygen

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WE have detected the absorption arising from magnetic dipole transitions between adjacent Zeeman components of the rotational levels of the oxygen molecule. The apparatus is essentially a microwave analogue of the radiofrequency nuclear magnetic resonance method.[1] Power from a frequency-stabilized 9360 mc/sec. oscillator is coupled into an oxygen-filled, cylindrical cavity placed in a uniform axial magnetic field. The cavity resonates in the TM011 mode so that the r-f and d.c. magnetic fields are perpendicular. A Wollaston wire bolometer is coupled to the cavity and forms one arm of a d.c. bridge. The axial magnetic field has a small 30 cycle/sec. modulation component so that in the region of an absorption line the microwave power into the bolometer is modulated, producing a 30 cycle/sec. unbalance signal in the bridge. This signal is amplified by a high-gain tuned amplifier and impressed on a lock-in mixer whose d.c. output indicates the magnitude and sign of the derivative of the absorption line (i.e., $d\chi''/dH$, where χ'' is the imaginary part of the magnetic susceptibility).

At atmospheric pressure two broad absorption lines were found for fields ranging up to 9 kilogauss. As the pressure was lowered these showed increasingly complex fine-structure. At an oxygen pressure of 1.5 cm Hg twenty-seven partially resolved components could be identified in the region from 5.4 kilogauss to the highest fields used. They showed no simple regularities in spacing, which varied from 380 to 60 gauss, or in intensity, which varied by at least a factor five. The half-widths of several of the larger lines could be determined; they range from 40 to 80 gauss and do not show the expected linear dependence with the field. Further, the half-widths are greater than those deduced from the pressure broadening of the 0.5-cm absorption band[2] of O_2 by factors ranging from 4 to 8. The largest resolved lines at the 1.5-cm pressure have χ'' values estimated to be 3×10^{-10} c.g.s. Noise fluctuations are about two percent of this.

As might be expected, the spectrum is not in accord with the low field Zeeman theory. Assuming pure Hund case (b) coupling in the $^3\Sigma$ ground state of O_2, the low field Zeeman formula predicts an absorption line at 6.9 kilogauss arising from $\Delta M=\pm1$ transitions between the Zeeman levels of the $J=1$ and 2 components of the $K=1$ rotational state, and a line at 10.3 kilogauss for the $K=3$, $J=2$ levels, as well as other lines at higher fields. However, even at 6.9 kilogauss the spin energy is a third of the average level-spacing in the spin triplets. Thus one expects a partial Paschen-Back effect for the fields used in the experiments. A more complete analysis of the line positions and intensities requires a high field Zeeman theory for molecular triplet states.

* Assisted by the ONR.

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Three-Photon Annihilation of an Electron-Positron Pair

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April 29, 1949

AFTER we had submitted the proof of our paper by the above title,[1] it came to our attention that this subject has recently been discussed by L. D. Landau, E. M. Lifshits, and I. Pomeranchuk.[2]

Landau and Pomeranchuk's work includes a discussion of allowed and forbidden annihilation processes. The earlier work by J. Pirenne and by J. A. Wheeler, to which we refer in our paper, as well as the conclusions which we have drawn from a detailed study of the special case of the three-photon annihilation, are in agreement with the general results of these authors.

However, Lifshits gives a formula for the differential cross section for three-photon annihilation which is in apparent disagreement with our result. As a consequence, he finds a lifetime of the triplet ground state of the positronium atom (8.8×10^{-8} sec.) which is shorter than ours by a factor 1.6.

Unfortunately, the brevity of Lifshits' report does not permit a comparison of the methods of calculation, and we have been unable to discover the source of the discrepancy.

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Electrolytic Deposits of Po in Extremely Dilute Solutions

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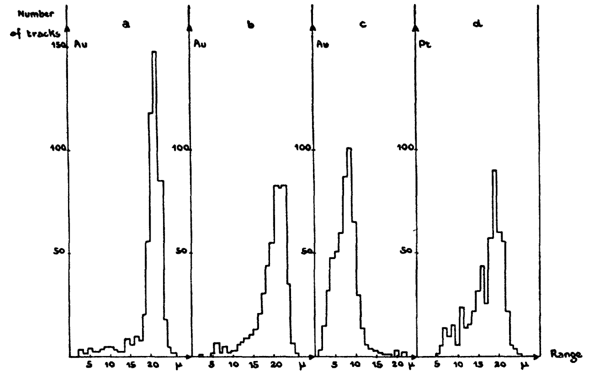
DURING the course of experiments which we are carrying out on the electrochemical behavior of radio-elements in extremely dilute solutions (between 10^{-10} and 10^{-14}N) we have made some observations which we think present an interest for nuclear physics research.

We obtain polonium deposits, either by electrolysis of its acid solutions (HNO_3, 1.5N) or by spontaneous deposition on surfaces of Au, Ag, Pt or Ni. After having measured the deposited quantity by means of a linear amplifier, the electrode is applied to an Ilford Nuclear Research plate type C2, and, after development, an examination of the plate enables us to establish the distribution of the Po atoms on the surface and that of the alpha ranges. This latter is generally based on



Initial cone: $0.44\cdot10^{-9}$N $0.11\cdot10^{-9}$N 10^{-13}N 10^{-13}N
Po deposit/cm^2: 0.06 e.s.u. $0.67\cdot10^{-4}$ e.s.u. $0.68\cdot10^{-4}$ e.s.u. $0.42\cdot10^{-4}$ e.s.u.

FIG. 1. Distribution of α ranges.

measurements of about 500 traces. The deposits correspond, except where the contrary is indicated, to $4-5\times10^{-5}$ esu/cm^2 (initial alpha emission of 60 to 80 particles min./cm^2 or 10^{-11} mg/cm^2). Note that the quantity necessary to cover 1 cm^2 of uniform monomolecular layer is 2650 e.s.u.

When the electrolysis is carried out in 10 cm^3 of a solution containing 1.5 esu Po in order to obtain a deposit on gold of 0.06 e.s.u./cm^2 a range distribution is obtained as given by Fig. 1*a*, where a well-defined peak is found corresponding to 21.5μ (in the Ilford emulsion) and which is just the normal alpha-range for Po according to our calibration. However a not negligible number of tracks are found which possess ranges inferior to the normal value: e.g. 2.6 percent of 14.5μ, 1 percent of 9.4μ etc.

If the deposit in the same solution is stopped at an intensity of 60α/min. cm^2 (4.10^{-5} e.s.u./cm^2), the distribution is considerably changed (Fig. 1*b*): the peak is here broader and corresponds to 19.5μ and the number of shortened tracks is much greater. In much more dilute solutions the deformation is more strongly accentuated, the maximum range and the distribution varying with the origin and the "history" of the metal, and probably with other experimental conditions. The quantitative reproductibility is consequently quite mediocre. As an example we reproduce the statistics corresponding to a deposit on gold foil in solution 10^{-13}N (Figs. 1*c* and 2). The peak here is only of 7.5μ. An analogous distribution was found for deposits obtained in 10^{-14}N solutions.

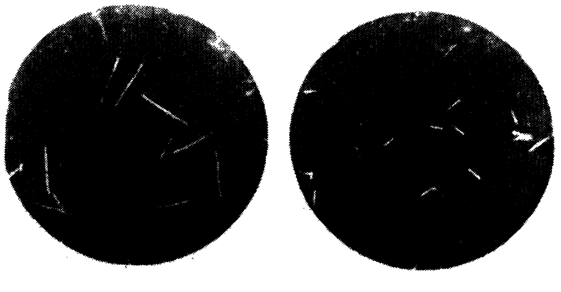


FIG. 2. 10^{-10}N 10^{-13}N
Po deposits on gold, in solution.

For deposits on Ag obtained under similar conditions to those just described (10^{-13}N) we have observed a nearly normal distribution (analogous to that shown in Fig. 1*a*). On Pt and on Ni, the distribution is intermediate between Au and Ag.

It is interesting to note that traces of nearly the same length tend to be grouped together on the various parts of the surface. Furthermore, in the more concentrated solutions (5×10^{-12} to 10^{-10}N) we frequently observed stars which correspond to aggregations containing thousands of Po atoms, and whose centers often seem to be situated at a certain depth inside the electrode. Our solutions being strongly acid, the possibility is excluded of considering the stars as of a radio-colloidal origin.

These experiments clearly show that a fraction of the Po atoms, the proportion varying with the conditions and especially with the nature of the support, slightly penetrates the interior of the metal. This signifies a partial absorption of the alpha-rays with a shortening of their ranges. The phenomenon is certainly related to the surface structure and could be explained by the existence of "active centers" postulated for the interpretation of the kinetic and energetic results for deposits obtained in extremely dilute solutions.[1]

We think that our results explain the observations of Chang[2] on the existence of numerous groups of reduced tracks in the alpha-"spectrum" of Po. Chang's conclusions have been severely criticized by Feather[3] and by Zajac, Broda, and Feather[4] and have not been confirmed in the more recent experiments of Wadey.[5] This author attributes the groups to the diffusion of Po in the metal, but the normal diffusion at room temperature is undetectable, according to the measurements of Rona and Schmidt;[6] $D<10^{-14}$ cm^2/day. Our experiments show that what has been observed by Chang is not the fine structure of the alpha-rays but the ultra-fine structure of the surface. They permit one to predict that the proportions of the feeble energy components of Chang's "spectrum" would strongly increase with the diminution of the source intensity.

Details of this research and its electrochemical aspects will shortly be described in the Journal de Physique et le Radium.

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The Forbidden Beta-Decay of Sr^{90} and Y^{90} *

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THE isotope Sr^{90} is a fission product which decays by β^--emission to Y^{90}. The half-life is $8\cdot10^8$ seconds and the energy release, including rest mass, is 2.04 mc^2 (kinetic energy 531 kev). The daughter product, Y^{90}, decays by β^--emission to Zr^{90}. The half-life for this transition is $2.25\cdot10^5$ seconds and the energy release is 5.40 mc^2 (kinetic energy 2.25 Mev). No gamma-radiation is observed. The decay scheme is pictured in Fig. 1 together with spin values and

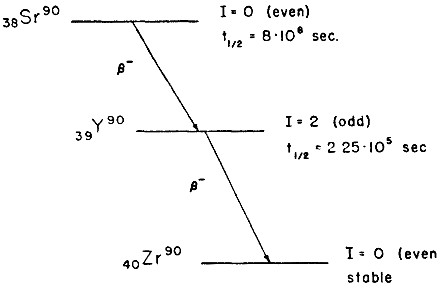

FIG. 1. Decay scheme for Sr^{90} and Y^{90}, showing spin and parity assignments as suggested in text.

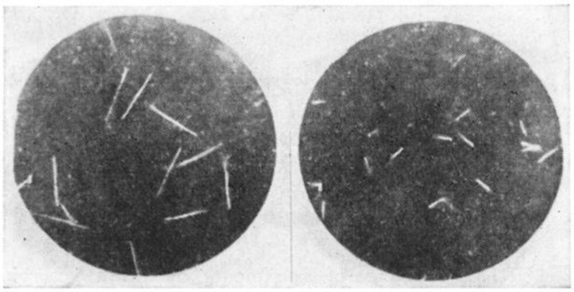

FIG. 2. 10^{-10}N 10^{-13}N
Po deposits on gold, in solution.