Artificial Alpha-Active Bismuth Isotopes

D. H. TEMPLETON AND I. PERLMAN
Radiation Laboratory and Department of Chemistry, University of California, Berkeley, California
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WHEN lead was bombarded with approximately 200-Mev deuterons in the 184-inch cyclotron, a great variety of nuclear reactions were noted. Fission has been demonstrated by the identification of radioactive fission products,[1] and a mixture of isotopes from Bi (element 83) to Au (element 79) has been partially identified. These were produced by reactions analogous to those reported from other irradiations with high energy particles.[2]

This report has to do with some new short-lived emitters of alpha-particles produced from high energy deuterons on lead. The alpha-activity was in very low abundance compared with the Geiger counter activity and was first observed in the unseparated target material. The decay curves could be resolved into 2-min., 9-min., 27-min., and 1–2-hr. components. The longest period was too weak for accurate half-life determination. The three longest periods were chemically identified with the bismuth fraction, but the chemical separation was too slow to permit observation of the 2-min. period. Lead which was bombarded with 100-Mev deuterons showed the 1–2-hr. and 27-min. periods, but the shorter periods could not be detected. Therefore, the 2-min. and 9-min. activities are probably of lower mass number than the longer-lived ones. All of these isotopes of bismuth are believed to be of lower mass number than 203 since lead, enriched in Pb^{204}, did not show any alpha-activity when bombarded with 20-Mev deuterons.[3]

The alpha-particle energies of the three longer periods were all in the range of 5.5 ± 0.3 Mev, as measured by an alpha-particle pulse analyzer.[4] The lack of precision was caused by the high background of electrons and by the inability to prepare extremely thin samples. Because these energies seem to low for alpha-particle half-lives of the order of minutes and since the bismuth fraction showed a great preponderance of electrons over alpha-particles, it is concluded that the alpha-emission represents but a small branching in the predominantly orbital electron capture decay. For example, a 30-min. period and a 100-min. period could be resolved out of the Geiger counter decay curve and, under the assumption that these are the same as the 27-min. and 1–2-hr. alpha-periods, alpha-particle to electron ratios of 7×10^{-4} and 6×10^{-5}, respectively, were calculated. The half-lives for alpha-decay for the 27-min. and 1–2-hr. activities then become about 1 month and 3 years if it is assumed that there is almost one electron emitted per orbital electron capture disintegration.

These data show that alpha-instability as reflected by the alpha-particle half-lives follows the same trend in the case of bismuth isotopes as that noted for the isotopes of polonium. In the case of polonium it has long been noted that there is a minimum half-life at ThC′ (Po^{212}) and that the half-lives increase both toward lower and higher mass numbers. This curve has been extended[5] to show that the half-life for Po^{208} is even longer than for Po^{210} but that the partial alpha-half-life then decreases again at lower mass numbers as exemplified by Po^{206}. In the case of bismuth, the earlier noted half-lives showed a decrease from heavier masses toward AcC (Bi^{211}) which has a 3-min. half-life. Recently Broda and Feather[6] reported that RaE (Bi^{210}) undergoes rare alpha-branching corresponding to a partial alpha-half-life of about 10^4–10^5 yr. Below RaE the half-life increases still further, as shown by the failure to detect alpha-activity in Bi^{209}. However, the present studies show that very light isotopes of bismuth ($Bi^{<203}$) again have measurable alpha-half-lives.

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[1] Perlman, Goeckermann, Templeton, and Howland, Phys. Rev. **72**, 352 (1947).
[2] Cunningham, Hopkins, Lindner, Miller, O'Connor, Perlman, Seaborg, and Thompson, Phys. Rev. **72**, 739 (1947).
[3] D. H. Templeton, J. J. Howland, and I. Perlman, Phys. Rev. **72**, 766 (1947).
[4] Ghiorso, Jaffey, Robinson, and Weissbourd, *An Alpha-Pulse Analyzer Apparatus*, Plutonium Project Record, **1413**, 17.3 (1946) (to be issued).
[5] D. H. Templeton, J. J. Howland, and I. Perlman, Phys. Rev. **72**, 758 (1947).
[6] E. Broda and N. Feather, Proc. Roy. Soc. London **A190**, 20 (1947).

Decay Scheme of 62-Day Isotope of Element 43 (Tc)

O. HUBER, H. MEDICUS, P. PREISWERK, AND R. STEFFEN
Swiss Federal Institute of Technology, Zurich, Switzerland
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THE disintegration of the 62-day isotope of element 43 (technetium), which is believed to have the mass number 95,[1] has been investigated. In addition to the known γ-lines at (0.201 ± 0.002) Mev[2] and (0.810 ± 0.005) Mev,[1] we found by measurements in a magnetic lens spectrometer[3] conversion, photo-, and Compton recoil electrons arising from two new γ-lines of (0.570 ± 0.002) Mev and (1.017 ± 0.010) Mev. Absorption measurements of the electrons and γ-rays showed that the 201-kev γ-line has a conversion coefficient of 0.044 ± 0.008. The relative intensities of the γ-lines were determined by analyzing the absorption curve in lead; the sensitivity of the counter[4] has been accounted for. The absorption coefficients for the experimental arrangement were determined empirically by means of standard γ-ray emitters. The strengths of the γ-lines were found to have the following ratios: $N_{201}:N_{570}:N_{810}:N_{1017}=0.7:0.4:0.3:0.03$. From the $\gamma-\gamma$-coincidence counting rate it follows that the 570-kev and 810-kev radiations are in coincidence with the 201-kev line. Up to now the disintegration had been assumed to take place only by orbital electron capture.[5] Cloud-chamber photographs also showed, however, positrons with energies up to 0.4 Mev. Comparing the number of positron tracks

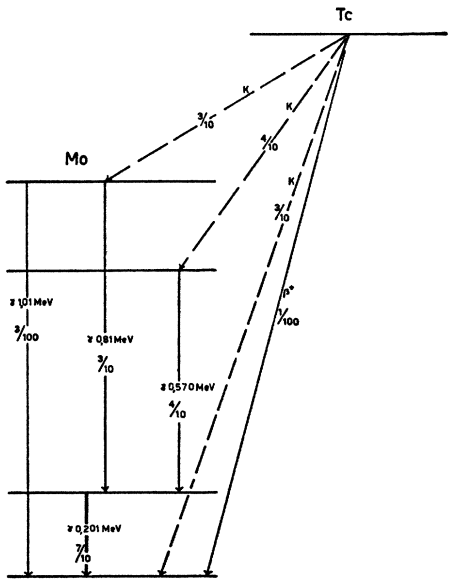

FIG. 1. Decay scheme of the 62-day Tc.

with the number of conversion electrons arising from the 201-kev radiation, as well as from the annihilation coincidence counting rate, we estimate that about 0.8 percent of the transitions take place by positron emission. The intensity ratios of x-rays and γ-rays show that one third of the electron capture transitions lead directly to the ground level. Summarizing these measurements, we propose a term scheme according to Fig. 1.

A detailed report will appear in Helv. Phys. Acta. We take pleasure in thanking Professor P. Scherrer for his stimulating interest in this work.

[1] J. E. Edwards and M. L. Pool, Phys. Rev. **72**, 384 (1947).
[2] D. C. Kalbfell, Phys. Rev. **55**, 422 (1939).
[3] The magnetic lens spectrometer used was designed by Dr. W. Zünti, and its description will appear in Helv. Phys. Acta.
[4] H. Bradt, P. C. Gugelot, O. Huber, H. Medicus, P. Preiswerk, and P. Scherrer, Helv. Phys. Acta **19**, 77 (1946).
[5] A. C. Helmholz, Phys. Rev. **60**, 415 (1941).

Use of Photo-Conductive Semiconductors as Amplifiers

EDMUND S. RITTNER
Philips Laboratories Inc., Irvington-on-Hudson, New York
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RECENT studies[1] at the Bell Telephone Laboratories have revealed that diamond may be employed as an electron amplifier by virtue of its internal secondary emission. Current amplification factors as high as 500 have been observed by exposure to electrons of 15,000-ev energy. Because of deleterious space charge effects produced by the impingement of electrons on the insulator and by electrons trapped at imperfections in the crystal, the experiments were performed with a pulsed beam technique and with an alternating field across the sample.

There are several extremely important advantages to be derived from the employment of a photo-conductive semiconductor rather than an insulator in this application:

(1) the above-mentioned space charge effects which oppose the flow of current through the specimen in the case of insulators will be absent in the case of semiconductors;

(2) the number of internal secondary electrons released per incident primary electron will be proportional to the quotient (energy of primary electrons/energy gap between filled band and conduction band); this quotient will be greater in the case of semiconductors by a factor of the order of 5 to 10;

(3) in analogy with the secondary photo-effect, the total number of electrons flowing through the semiconductor circuit will, in most cases, far exceed the number of electrons internally released by the bombarding electrons;[2]

(4) the loss of electrons via external secondary emission will be less in the case of semiconductors;[3]

(5) the impedance of the semiconductor device will be of a more suitable magnitude for use in conjunction with usual electronic circuits, the "dark" current being entirely analogous to the no-signal plate current in a vacuum tube amplifier.

Optimum results will probably be achieved with thin specimens of the same order of thickness as the penetration depth of the primary electron beam. Single crystals, in general, present the advantage of extremely high charge carrier mobility relative to polycrystalline samples, although even the latter can be employed to great advantage.

The amplification factor will be proportional not only to the charge carrier mobility and the energy of the incident electrons but also to the field strength applied to the sample, limitations being imposed by the total power input, which will cause heating of the specimen. Care should be exercised to prevent the deflection of the incident beam to an electrode of the sample. For low primary beam intensities the increase in current through the semiconductor on bombardment will be a linear function of the beam intensity.

The main disadvantage of this type of amplifier is the fact that highest amplification factors can be obtained only at a sacrifice in frequency response.[4] The frequency response can be improved with an attendant reduction in amplification factor by exposure of the sample to steady background illumination, by raising the temperature of the sample, or by incorporation of the proper impurities into the photo-conductive layer.

Preliminary experiments have been carried out with a thin polycrystalline layer of selenium deposited on a glass base furnished with two tungsten wire electrodes 5 mm apart. Selenium was chosen because of the ease with which it can be fashioned into a photo-conductive cell. The data are shown in Table I.

These results are subject to improvement by factors of one or more orders of magnitude by changes in the geometry of the electrode configuration and in the tech-