The Probability of Excitation of the Nucleus ^{206}Pb in the α-Disintegration of Polonium

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June 1, 1946

A FULL account has recently been published[1] of work already briefly reported[2] which would indicate the presence of 12 lines of feeble intensity, hitherto unobserved, in the α-particle spectrum of polonium. The spectrum was obtained using the Princeton cyclotron magnet to produce "semicircular" focusing and was found to cover an energy range of 1.6 Mev on the low energy side of the main line. This spectrum extended over 10 cm on the photographic plate used as detecting instrument. Adequate resolution was therefore available for the study of even complicated fine structure, and conditions would have been perfect for exact determinations of energy if it had been possible to employ sources of considerably greater strength than those actually used ($\frac{1}{10}$ to $\frac{1}{3}$ mC). On account of this limitation in source strength, however, it was necessary in the experiments in question to fix the positions of the lines and to deduce relative intensities by microscopic examination of the plates and the counting of single α-particle tracks.

In discussing the α-particle spectra which he obtained in this way, Chang makes the natural assumption that the fine structure observed is nuclear in origin, and he points out fully how this assumption introduces considerable difficulties when taken in relation to the accepted theory of α-disintegration. He discusses also the measure of concordance between his results, as he interprets them, and the information available regarding the γ-rays of polonium. Although he notes an apparent discrepancy here, he concludes "In general we may say that, as far as energy and intensity are concerned, these γ-ray lines are compatible with the α-particle groups" (page 73). It is the purpose of this note to examine this conclusion in respect of the intensities; as concerns the energies it is obviously unexceptionable.

It may be recalled that in 1931 Curie and Joliot, having failed to identify the high energy γ-rays of polonium by the ionization method, using sources of 8–10 mC strength,[3] succeeded in detecting this radiation and investigating its absorption in lead only when a source of 100 mC strength was employed.[4] Bothe and Becker had previously reported the radiation,[5] and had examined its properties using a point counter as detector,[6] and somewhat later Webster[7] published the results of an investigation in which a pressure ionization chamber was used in a similar study. In 1935 Bothe[8] obtained the "natural" β-particle spectrum in a spectrograph of high collecting power (using a 30 mC source), and in the following year the "excited" spectrum of the photoelectrons produced in lead by the γ-rays.[9] The absorption experiments indicated the presence of a softer and a harder component in the radiation, and on the basis of the natural and excited spectrum results the latter component was shown to consist of two main "lines" of quantum energies 0.80 and 1.07 Mev. It is in respect of these lines that existing information regarding intensities is most complete. Calibrating his pressure chamber with the 2.62 Mev γ-rays from thorium C″, Webster deduced $(12\pm1)\times10^{-6}$ for their combined intensity, per atom disintegrating, and Bothe and Becker concluded in effect that, on the basis of equal members of disintegrations, the intensity of these radiations as measured by their counter was 6.6×10^{-6} of that of the γ-rays of a sealed radium source. The two estimates are generally concordant, and taking count of the difficulties of standardization we may say that the absolute intensity of the combined radiations is $(10\pm4)\times10^{-6}$ quantum per disintegration. On the other hand Chang has concluded that the excitation of the nuclear states of ^{206}Pb of more than 0.80-Mev energy of excitation, due to the emission of polonium α-particles of less than the normal energy, is 2.3×10^{-4} per disintegration, with a possible error of 50 percent.

It would appear that, in spite of his quoted remark, there is a very real discrepancy here which can only be resolved if the γ-rays in question are internally converted to a high degree, or if de-excitation of the nucleus takes place in multiple cascade—or by the emission of radiation other than γ-rays. Bothe's experiments,[8] however, dispose of the first possibility: it can be calculated, on the basis of the data in the original paper, that the intensity of the natural photoelectron lines is in no case greater than 10^{-7} per atom disintegrating. We are led, therefore, to examine the possibility of cascade emission.

If we accept Chang's intensities, the average energy of excitation of the residual nucleus in the polonium disintegration is 445 ev. Taking 10^5 ev as a reasonable mean energy for the cascade γ-rays (reasonable, that is, on the basis of the nuclear levels revealed by the fine structure spectrum), we obtain a hypothetical "soft" γ-ray intensity of 4.45 quanta per thousand disintegrations. Such a component of the γ-radiation could not well have been missed in the early investigations—particularly in those of Curie and Joliot.[3] It would appear, therefore, that if Chang's intensities are correct some entirely new effect is in question.

There are other reasons for coming to the same conclusion. In a paper shortly to be published, Broda and the writer will show that the 4.2 minute β-activity, previously attributed to ^{204}Tl, in reality belongs to ^{206}Tl. The disintegration in this case, therefore (giving rise to β-particles of maximum energy 1.7 Mev, but no γ-rays) results in the same residual nucleus as does the disintegration of polonium. It would seem that there must be something distinctly peculiar in the nuclear level system if there are 12 states energetically capable of being excited in the β-disintegration which are not appreciably excited. Qualitatively one would say that excitation of the residual nucleus is a more frequent feature of β-disintegration than of α-disintegration.

It may be remarked in conclusion, that even if Chang's intensities do not eventually prove to be correct large values of the spin change in the α-disintegration are still required to account for the intensities of the less-hard γ-rays (quantum energy 0.2 to 0.43 Mev) reported by Bothe and Becker and Webster. Unless the 0.8-Mev state is the first excited state of the ^{206}Pb nucleus, lower states are required to account for these radiations, and the excitations of these states appear abnormally small. It may be that there is some connection between this conclusion and the observation of Waldman and Collins[10] that a metastable level of 1.6 minutes half-value period and about 0.3-Mev energy of excitation can be excited by the action of high energy x-rays on lead.

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[7] H. C. Webster, Proc. Roy. Soc. **A136**, 428 (1932).
[8] W. Bothe, Zeits. f. Physik **96**, 607 (1935).
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High Energy Carbon Nuclei

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May 28, 1946

$C_6^{12(++++++)}$ AND other nuclei having approximately the same e/m ratio as deuterons can be accelerated in the cyclotron under similar conditions to those required for the deuteron beam.[1] Their kinetic energy will be greater in the ratio of their mass to the mass of the deuteron. By using them, new types of nuclear reactions might be detected, namely, ones involving higher excitation energies than hitherto known. CO_2 was the most satisfactory source of carbon ions. A shallow ionization chamber was used to identify the beam, and to measure its specific ionization and range. Precise measurements cannot be made until the intensity can be increased with the help of a specially built ion source. The Gamow theory of penetration of nuclear barriers has been applied for the case of light bombarding nuclei. Penetration of most nuclei by s waves can be expected even at lower energies than now reached (96 Mev for carbon), although the maximum cross section will be reached only at considerably higher energies, where the contribution of higher incident angular momenta becomes important. The electric moment induced in the bombarding particles at the approach of a nucleus may lead to the splitting off of alpha-particles before the potential barrier can be penetrated. The tracks due to the 96-Mev carbon particles accelerated in the 60″ cyclotron were recorded in photographic emulsions. Their grain density, track length, and the total number of grains have been measured and plotted in relation to the specific ionization and the air equivalent range. Some of the microphotographs taken show elastic collisions with various nuclei. A few cases that may represent inelastic collisions were observed. Two star-shaped inelastic collisions were found and analyzed.

* Abstract of thesis submitted by Cornelius Tobias to the faculty of the University of California in partial fulfillment of the requirements for the degree of Doctor of Philosophy in 1942, and not published because of the war.

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Assignment of Mass to 46-Hr. Samarium and 9.2-Hr. Europium by a Mass Spectrograph

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June 24, 1946

A NITRIC acid solution of Sm_2O_3 was irradiated by slow neutrons to produce the 46-hr. samarium activity reported in Seaborg's table.[1] Part of this irradiated sample was placed on the filament source of a mass spectrograph. By operation of the spectrograph the samarium isotopes were separated according to mass on a photographic plate. After removal from the spectrograph, this plate was placed face to face with another photographic plate. With the passage of time the particles emitted from the active isotopes on the first plate gave rise to a developable image on the second plate. After both plates were developed, the original plate showed the normal spectrum of samarium (Sm^+ and SmO^+) while the second plate showed only two lines. These corresponded to masses 153 and 169 on the original plate. Because of the emission of the form SmO^+ the activity at mass 169 was ascribed to the same isotope as was the activity at mass 153. A decay curve of a second portion of the irradiated samarium solution showed that more than 95 percent of the activity was caused by the isotope with 46-hour half-life. Thus we may conclude that the mass of 46-hr. samarium is 153.

A nitric acid solution of Eu_2O_3 was irradiated by slow neutrons to produce the 9.2-hr. europium activity reported in Seaborg's table.[1] The same mass spectrograph technique was applied to this sample as to the samarium sample. In this case the second photographic plate showed a single line corresponding to mass 152 on the original plate. A decay curve of a portion of the irradiated europium solution showed that more than 95 percent of the activity was caused by an isotope with 9.2-hr. half-life. Thus we may conclude that the mass of 9.2-hr. europium is 152.

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Activation of Ag (225 d.) by Resonance Neutrons

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June 25, 1946

BY activation of Ag in the Argonne heavy water pile it is shown that the Cd filtered neutrons activating the long period of Ag (225 d.) are strongly absorbed in both Ag and Au. As this is also the case for the resonance neutrons leading to Ag^{110} (22 sec.) but not for those leading to Ag^{108} (2.3 min.),[1] it is plausible to assign Ag (225 d.) to an isomeric state of Ag^{110}. Mass assignment of isomers through identification of neutron resonance groups may be a useful method in other cases and is now being applied to Ir.

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