The Alpha-Particles of Radium

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The abundance of α_{188} of Ra^{226} was determined with an alpha-particle spectrograph to be 5.7±0.3 percent. The nomenclature α_{188} refers to the alpha-group populating the excited level of the residual nucleus which is 188 kev above the ground state.

A limit of 0.1 percent was determined as the maximum abundance of any alpha-group in the region 300 to 800 kev below α_0 of Ra^{226}. A. Ghiorso, utilizing an alpha-pulse analyzer, lowered this limit to 0.02 percent in the region 400 to 1200 kev below α_0.

In the course of the measurement of the alpha-particle spectra of a considerable number of artificial alpha-emitters using a magnetic spectrograph, some secondary standards for energy calibration have been adopted in relation to the primary standard RaA whose alpha-particle energy was determined accurately as 5.9981 ±0.0008 by Briggs.[1] Among these standards is Ra^{226} which has been used primarily to determine the dispersion of the instrument by measuring the displacement between the two well-known peaks separated by 185 kev. The abundances of the alpha-groups are used in testing agreement between measured data and alpha-decay theory, and since there have been some minor differences between published values of the abundances, a new determination has been made.

That Ra^{226} has complex structure could be inferred from the early measurement of an 188-kev gamma-ray of Hahn and Meitner.[2] This gamma-ray was shown to be partially converted[3] and the gamma-ray energy determined as 186 kev by spectrographic measurement of the conversion electrons.[4]

The alpha-particle group for the transition to this excited state was observed with an alpha-ray spectrograph by Rosenblum and co-workers,[5] who reported its abundance as ~6.5 percent. The abundance was confirmed as 6.5 percent in another measurement by Bastin-Scoffier.[6] Using an ionization chamber coupled to a pulse-height analyzer, members of this laboratory[7] reported a lower value (4.8 percent) for the abundance of the low energy group. In addition to this well-defined group, Rosenblum and co-workers[5,6] found some evidence for a weak group of 600 kev lower energy than the main group. In referring to alpha-groups of a particular nuclide we shall designate by α_0 that group

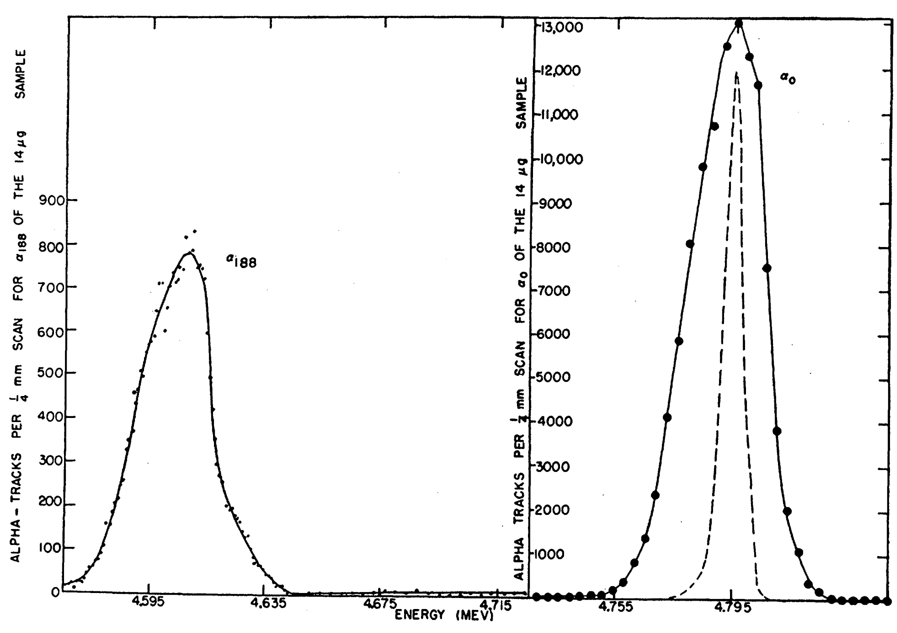

FIG. 1. · Alpha-tracks per $\frac{1}{4}$-mm scan for α_{188} of the 14-microgram sample. • Alpha-tracks per $\frac{1}{4}$-mm scan for α_0 of the 14-microgram sample. The ordinate scale is that shown on the center of the figure. --- Curve showing the shape of the α_0 peak obtained with the 0.3-microgram sample. The ordinate scale is 1/20 that shown in the center of the figure. The abscissa scale is the same for all three alpha-groups.

[1] G. H. Briggs, Proc. Roy. Soc. (London) **A157**, 183 (1936).
[2] O. Hahn and L. Meitner, Z. Physik **26**, 161 (1924).
[3] E. Stahel and W. Johner (1931), quoted by P. Falk-Varaint and J. Teillac, J. phys. et radium **12**, 659 (1951).
[4] Cork, Branyan, Stoddard, Keller, LeBlanc, and Childs, Phys. Rev. **83**, 681 (1951).
[5] Rosenblum, Guillot, and Bastin-Scoffier, Compt. rend. **229**, 191 (1949); S. Rosenblum, Compt. rend. **195**, 317 (1932).
[6] G. Bastin-Scoffier, Compt. rend. **233**, 945 (1951).
[7] Karraker, Ghiorso, and Templeton, Phys. Rev. **83**, 390 (1951).

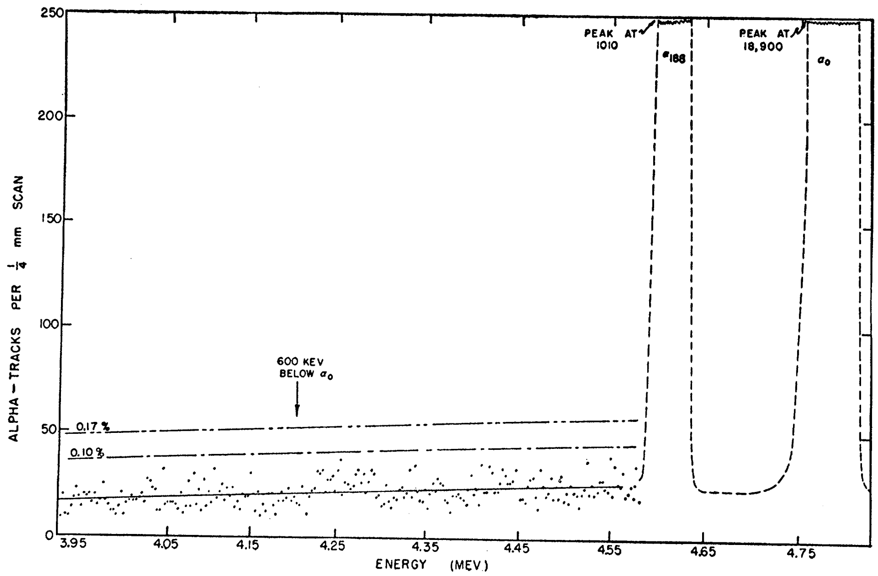

FIG. 2. · Alpha-tracks per $\frac{1}{4}$-mm scan. --- Curve indicating the position and the abundances calculated for α_0 and α_{188} from a short exposure. —— Average background below α_{188}. ———— A straight line parallel to the average background and 0.17 percent of the α_0 peak height above the average background. ——— A straight line parallel to the average background and 0.10 percent of the α_0 peak height above the average background.

believed to be the ground state transition, and for other groups the energy levels in kev above the ground-state to which the groups lead will be entered as subscripts.[8] The three groups mentioned would be accordingly, α_0, α_{188}, α_{600}.

The source employed in the present measurement consisted of 14 micrograms of Ra^{226} as radium chloride sublimed in vacuum onto a $\frac{1}{8}\times 1$ inch band on a platinum plate by a technique described elsewhere.[8] The magnetic alpha-particle spectrograph and its operation have also been described.[8,9]

The solid curve of Fig. 1 shows the results of 21-hour exposure for the alpha-particle spectrum in the range ~4.5–4.8 Mev with the ordinate showing the number of alpha-tracks in each $\frac{1}{4}$-mm wide (one field of view of the microscope) scan across the receiver photographic plate. Because of the disparity in track counts for the two peaks, the ordinate scales have been made tenfold different. Because of source thickness, the half-width of the peaks are about 28 kev, as compared with 5–8 kev obtained with other sources in this instrument under best conditions. Nevertheless, the resolution of the two peaks in Fig. 1 is complete, and the abundances of the alpha-groups [5.5 percent ($\pm$0.2) for the low energy group] should be reliable within the indicated limits of error.

The abundances (Fig. 1) were determined by counting all of the tracks in the low energy peak (almost 26,000) and those in every fourth $\frac{1}{4}$-mm scan for the principal peak (109,000). The measured abundance of the low energy group was 5.6 percent, but this was revised downward to 5.5 percent because of the different geometry factor applicable to the two groups. This difference is a consequence of the longer path followed by the high energy particles because the photographic plate is not normal to the trajectory of the alpha-particles but 60° to the normal. Abundance measurements were also made on three other samples for all of which fewer tracks were registered. The values obtained were 6.0, 5.8, and 5.5 percent for the abundance of the low energy group. The value that we shall adopt is 5.7$\pm$0.3 percent, which is the average of the four measurements and the limit of error encompasses all of them.

In order to illustrate the resolution attainable with thinner sources an analysis of the main peak was made with a source consisting of only 0.3 microgram Ra^{226}. The peak is shown with a broken line in Fig. 1, and the width at half-maximum is only 6 kev as compared with 26 kev for the thicker source. In this particular measurement the magnetic field was such that the low energy group did not register on the photographic plate.

As mentioned, a weak group of about 600 kev lower energy than the ground state transition has been reported,[5,6] and its abundance was given in the second publication as 0.17 percent. This group would be placed at 4.20 Mev, and in the present experiments the region from 4.0 to 4.5 Mev was examined. The results are shown in Fig. 2, from which it is deduced that no peak of greater than 0.1 percent abundance could be present.

As seen in Fig. 2 the inability to distinguish groups in lower abundance than 0.1 percent so distant from the main groups is due to an extensive and nearly constant tailing on the low energy side of the peaks. This phenomenon is as yet unexplained. Incidentally, the integrated number of alpha-tracks over this wide range is considerable, but by the same token they must come proportionally from both alpha-groups so that the ratio of abundances of the two groups would not be affected. Since the limitation of discrimination of an alpha-group

[8] Asaro, Reynolds, and Perlman, Phys. Rev. **87**, 277 (1952).
[9] F. L. Reynolds, Rev. Sci. Instr. **22**, 749 (1951).

in this region is not a great deal lower than the reported[5,6] intensity of the peak α_{600}, a definite disagreement cannot be suggested. However, A. Ghiorso in this laboratory has made a careful examination of Ra^{226} with an alpha-particle pulse analyzer over the energy range 3.6–4.4 Mev and set a limit of 0.02 percent for the abundance of any group in this interval.

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Evaluation of Range Straggling for Heavy Particles*†

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From the formula developed by Lewis for the differential range distribution of heavy, charged, nonrelativistic particles, an integral range distribution is obtained. The latter is evaluated for 2- to 500-Mev protons in Al to show, in a practical way, how the distribution differs from a Gaussian, as evidenced by its shorter-than-average range tail. The extent to which this tail increases the mean range and makes it different from the most probable range is indicated. Values for the range straggling are also given.

THE deviation of the range distribution of fast, but nonrelativistic, heavy charged particles from a Gaussian form is the subject of a recent paper by Lewis.[1] Because a large fraction of a particle's energy can be lost in a single collision, this distribution has a longer tail on the side of shorter-than-average range. While the existence of the long tail is known from previous calculations[2–6] of the corresponding distribution in energy loss, this earlier work has been done assuming the total energy loss to be small compared with the initial energy.

Lewis, making the opposite approximation, finds the differential range distribution in the form

$$f(y)=(2\pi)^{-\frac{1}{2}}h(y)\exp(-y^2/2),$$

where $y=(x-\langle x\rangle)/\beta_2^{\frac{1}{2}}$ (i.e., the difference between the

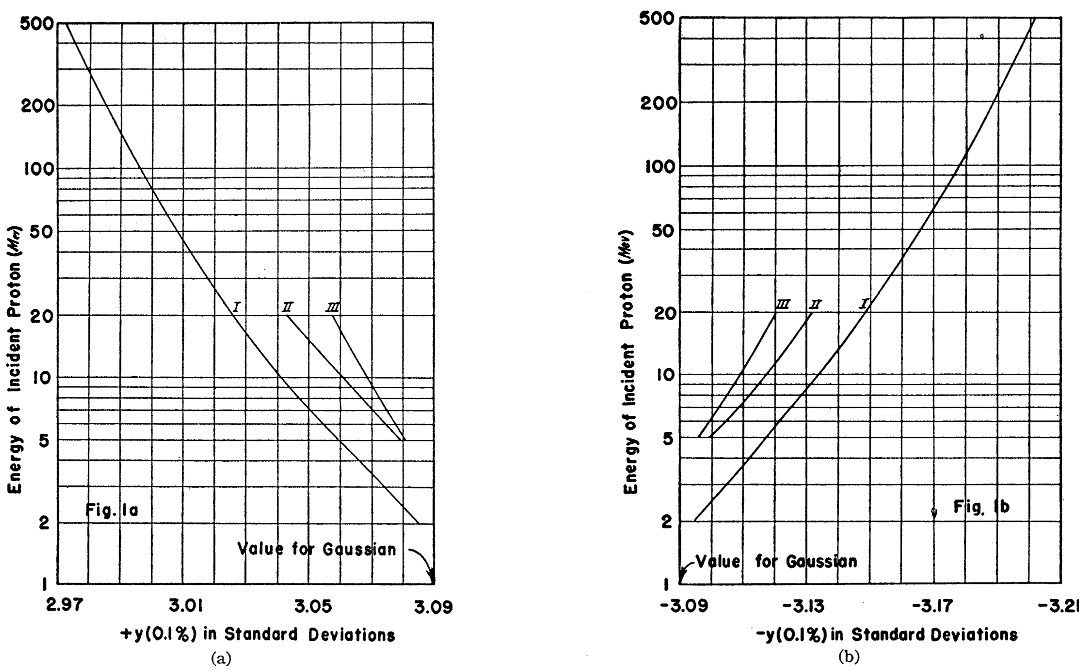

FIG. 1. Variation with incident particle energy of the positions of the 0.1 percent tails of the integral range distribution. Figure 1(a) is for $+y$ (longer than average range) and Fig. 1(b) for $-y$ (shorter than average range). Curves I are for protons in Al; II, protons in Cu; and III, deuterons in Al.

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† A more complete account of this work is given in unpublished University of California at Los Angeles Technical Report No. 9 (1952).
‡ AEC Predoctoral Fellow.

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[3] E. J. Williams, Proc. Roy. Soc. (London) A125, 420 (1929).
[4] L. Landau, J. Phys. (U.S.S.R.) 8, 201 (1944).
[5] O. Blunck and S. Leisegang, Z. Physik 128, 500 (1950).
[6] W. Schultz, Z. Physik 129, 530 (1951).