was very carefully searched but nothing above background was detected.

Another sample of the same material was mounted on a thin foil and used as a β-ray source to look for the conversion electrons reported by Walke, in an attempt to find some positron emission. In both cases no detectable particle radiation was found of sufficient energy to penetrate our counter window. These results indicate that Cr^{51} decays simply by K-capture with the emission of one soft γ-ray.

7. CONCLUSIONS

In the two K-capture elements tested there is no evidence of annihilation radiation resulting from the emission of very slow positrons. In our experiments no positron of energy lower than about 100 kev could enter our counter. It is believed that it would be profitable to pursue this problem further, however, since in many cases the evidence for $\bar{K}$-capture would not exclude the possibility of slow positron emission.

We take great pleasure in thanking Mr. J. E. Robinson for the very able assistance he rendered in the many long "runs" which were involved in this work and its preliminaries. Our grateful thanks are also due to Dr. Lin-Sheng Tsai, to Dr. Gerhard Friedlander, and to Mr. W. H. Burgus for their assistance and counsel on matters chemical.

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The Beta- and Gamma-Rays of Rb^{86}

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The beta- and gamma-rays of Rb^{86} (19.5 d) have been measured in a magnetic lens spectrometer. Measurement of the energies of photoelectrons produced in a lead radiator shows one line corresponding to a gamma-ray of energy 1.081 Mev. The beta-ray spectrum is resolvable into two groups with end point energies of 1.822 and 0.716 Mev.

I. INTRODUCTION

TWO rubidium isotopes of 18 minutes and 19.5-day half-lives were reported by Snell.[1] Later Helmholz, Pecher, and Stout[2] showed that the activity of 19.5 day half-life must be attributed to Rb^{86}. They measured the beta-ray end point by absorption in aluminum and obtained a value of 1.56 ± 0.05 Mev. Haggstrom[3] measured the beta-ray spectrum of this isotope in a solenoid type magnetic analyzer. She made a Fermi plot of her data and found a beta-ray end point of 1.60 ± 0.03 Mev. The Fermi plot was not a straight line at the low energy end, but she attributed this to the fact that Rb^{86} belongs to the second forbidden class.

Preliminary work in this laboratory showed that a low intensity gamma-ray accompanies this activity. A rough estimate of the energy of the gamma-ray was obtained by measuring the coincidence absorption of Compton electrons produced in an aluminum radiator. The value obtained for the energy of this gamma-ray was approximately 1 Mev. In order to determine the disintegration scheme, the authors decided to investigate the spectrum in a magnetic lens spectrometer. The spectrometer has been described elsewhere.

II. PURIFICATION OF SOURCE MATERIAL

Strong sources of Rb^{86} were obtained from Oak Ridge. The main impurity in the source

[1] A. H. Snell, Phys. Rev. 52, 1007 (1937).
[2] A. C. Helmholz, C. Pecher, and P. R. Stout, Phys. Rev. 59, 902 (1941).
[3] E. Haggstrom, Phys. Rev. 62, 144 (1942).

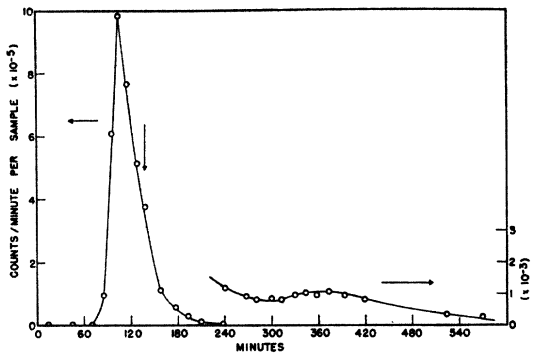

FIG. 1. The separation of Rb^{86} from Cs^{134} in an ion exchange column.

appeared to be Cs. The activity of Cs^{134} was found to be present and the gamma-rays of Cs^{134} were identified when the gamma-ray spectrum from the unpurified sample was measured. The separation of small quantities of Cs from Rb has, until recently, been quite a tedious process. However, with the advent of the ion exchange resins, and tracer techniques, the separation of these two elements has become quite simple.[4]

The ion exchange column used in these experiments was 1.5 meters long and 1 cm in diameter. It was filled with the resin called "Amberlite 200." The column was prepared by filling it with

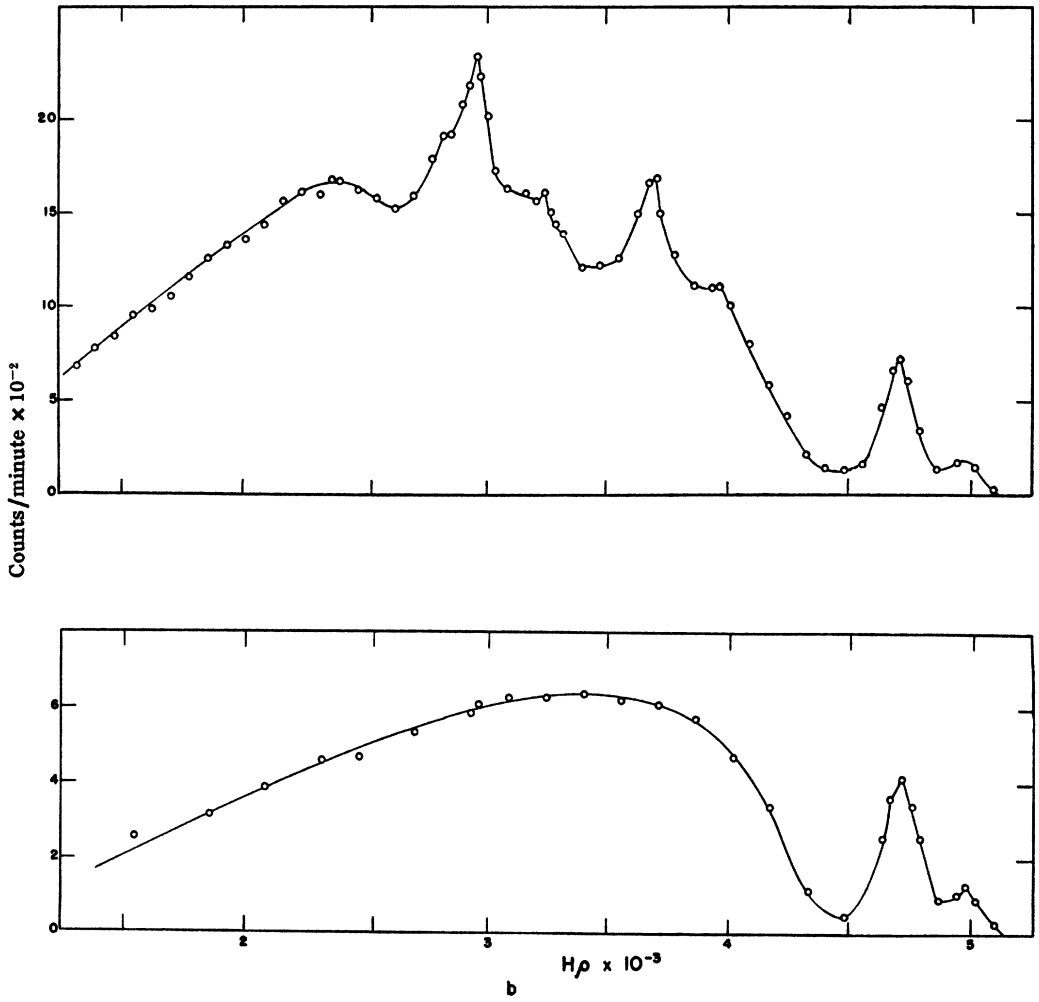

FIG. 2. Photoelectrons ejected from lead by gamma-rays. 2a. Unpurified source, showing gamma-rays of Cs^{134} and Rb^{86}. 2b. Purified source; gamma-ray of Rb^{86}.

[4] The authors are indebted to Dr. G. E. Boyd of Clinton Laboratories for calling their attention to this method. Many papers describing this method are to be found in the *Journal of the American Chemical Society* for November, 1947.

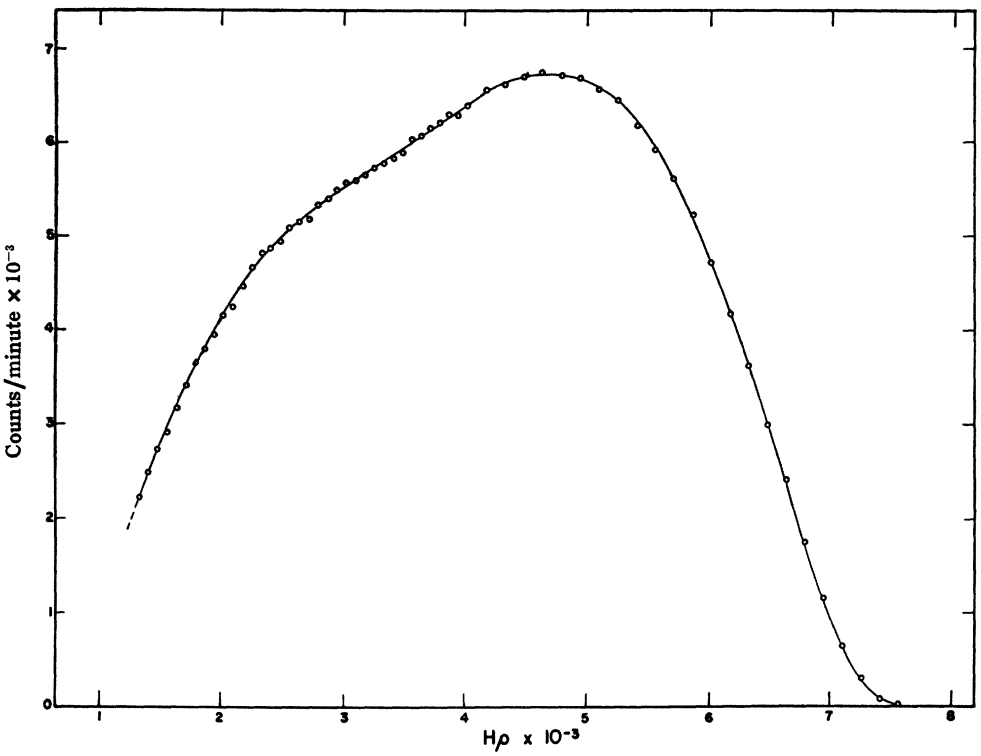

FIG. 3. The beta-ray spectrum of Rb^{86}.

the resin and a solution of 0.1 N HCl. The source material, Rb_2CO_3, was dissolved in HCl and enough additional acid was added to make the solution 0.1 N in HCl. The solution was then poured into the column and the column was washed, or eluted, with 0.1 N HCl at a constant rate. The flow rate used in these experiments was about 2 cm^3/min.

In order to follow the separation, a standard volume of the solution issuing from the bottom of the column was taken every few minutes. The activity of this standard sample was then measured with a counter. When the activity became too strong for counting, the sample was suitably diluted and an aliquot part therefrom taken for counting. A plot of the activity of successive samples against the time is shown in Fig. 1. It will be seen that the peak associated with rubidium is quite well separated from the small peak associated with cesium. The rubidium sample separated for study was taken off shortly after the rubidium peak had been passed, as indicated by the vertical arrow in Fig. 1. In some experiments the purified rubidium was again run through a freshly prepared ion column. After purification the solution containing rubidium was evaporated to dryness and was used in the preparation of sources.

III. MEASUREMENT OF THE GAMMA RADIATION

Gamma-ray sources were prepared by packing the solid salt into a cylindrical copper capsule whose walls and base were just thick enough to stop all beta-rays. A lead radiator, of surface density 26 mg/cm^2, covered the base of the cylinder to serve as a source of photoelectrons. The capsule was then placed in the magnetic lens spectrometer and the number of secondary electrons (photoelectrons and Compton electrons) were counted as a function of the current through the coil.

The results of the measurement on the purified source are shown in Fig. 2b, in which the counting rate is plotted as a function of the momentum of the electrons (in gauss-cm). There are

two peaks, one at 4685 $H\rho$ and one at 4950 $H\rho$. These are the K and L photo lines excited in lead from a gamma-ray of 1.081 ± 0.006 Mev. If the binding energies of the K (0.088 Mev) and L (0.016 Mev) shells of lead are added to the energies of the respective photo-lines, one obtains $E_\gamma = 0.993 + 0.088 = 1.081$ Mev and $E_\gamma = 1.068 + 0.016 = 1.084$ Mev. In addition the distribution of the accompanying Compton electrons may be seen.

In Fig. 2a the results of a similar measurement taken earlier using the unpurified sample are shown. In addition to the lines shown in Fig. 2b, K and L lines from a gamma-ray at 0.795 Mev, and K lines from gamma-rays at 0.604 and 0.568 Mev are to be seen. These lines have been observed previously by Elliott and Bell[5] and are to be attributed to Cs^{134}.

Since the original source contained impurities, it was necessary to show that the 1.081 Mev line is to be attributed to Rb^{86}. This was done by measuring the K-photo peak and selected points on the Compton distribution for the purified source over a long period of time. These measurements were monitored by a small uranium source which could be placed in front of the counter window in the instrument. All points followed a 19.5-day period to within ± 5 percent.

IV. MEASUREMENT OF THE BETA-RAY SPECTRUM

The beta-ray spectrum was measured with sources of surface densities 0.45 mg/cm² to 9 mg/cm², on backings of Zapon film, paper, or aluminum foil weighing less than 1 mg/cm². A typical example is shown in Fig. 3. It will be noticed that the shape appears to indicate a complex spectrum. The Fermi plot for this spectrum is shown in Fig. 4.

An inspection of the Fermi plot reveals that the points near the end point drop slightly below

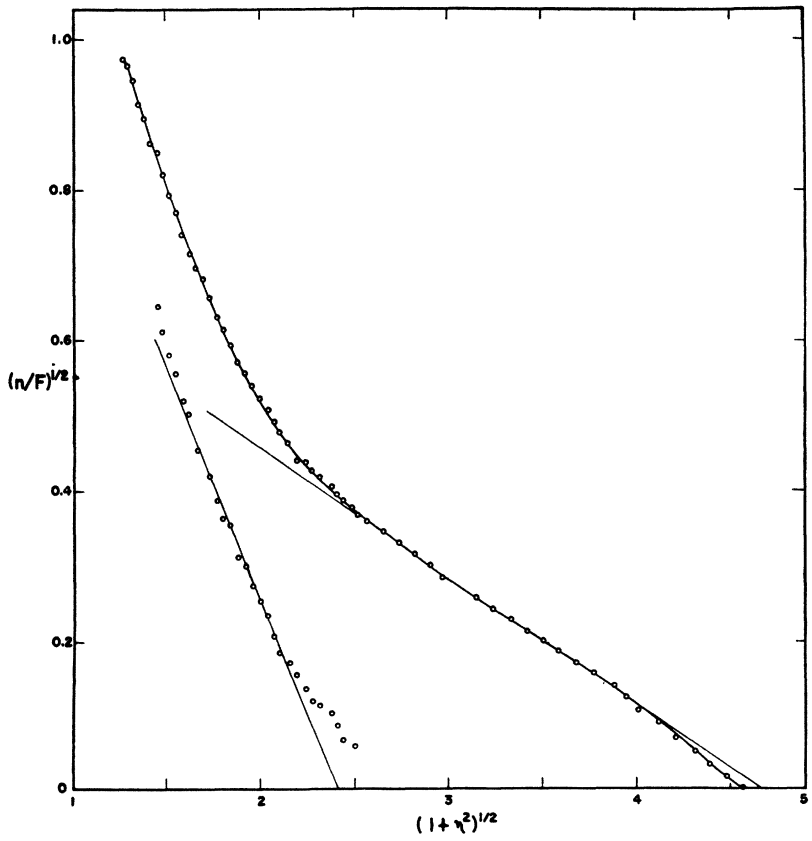

FIG. 4. Fermi plot of the beta-ray spectrum of Rb^{86}.

[5] L. G. Elliott and R. E. Bell, Phys. Rev. 72, 979 (1947).

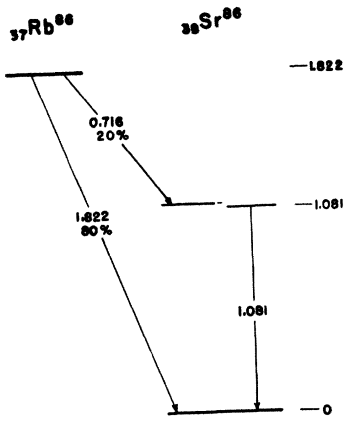

FIG. 5. Disintegration scheme of Rb^{86}.

the best straight line that can be put through the remainder of the points in the high energy group. This effect was found in every spectrum which was analyzed. The explanation is probably to be found in the fact that the spectrum of Rb^{86} belongs to the second forbidden class. The end point obtained for the extrapolated straight line is 1.855 Mev, while the actual end point is 1.822 Mev. A definite deviation from this straight line at the lower energy end allows one to separate out a second beta-group with an end point of 0.716 Mev.

Six determinations of the high energy end point have been made. These give an average value of 1.822 ± 0.014 Mev. The lower energy group has an average end point of 0.716 ± 0.02 Mev. The difference between these two end points is 1.106 Mev, which is to be compared with the gamma-ray energy of 1.081 Mev previously mentioned. The small discrepancy is probably due to the difficulty of determining accurately the end point of the inner beta-group.

The low energy beta-group comprises 20 percent of the total beta-emission. This fraction has been observed to remain approximately constant in data taken over a period of two half-lives.

V. DISCUSSION

An energy level scheme can now be drawn up for the disintegration of Rb^{86} into Sr^{86}. This is shown in Fig. 5. It will be seen that in 80 percent of the disintegrations there is a direct transition to the ground state with the emission of a beta-ray of 1.822 Mev, and in the remainder, a transition to an excited state of Sr^{86} with the subsequent emission of a gamma-ray of energy 1.081 Mev. A confirmation of this scheme has been found by Mr. E. T. Jurney who has made coincidence measurements on this material. He finds that there are no gamma-gamma-coincidences and that there are beta-gamma-coincidences only for beta-energies less than 0.6 Mev.

The authors wish to express their indebtedness to Professor L. R. Merritt of the Chemistry Department for his help in work on ion exchange columns. This work has been supported by the Office of Naval Research under Contract N6ori-48, T.O. 1.