include possible systematic errors in the mass spectrometer.[1] The actual mean deviations are about one-third of the deviations quoted in this table. The following upper limits were set for the existence of other neodymium isotopes:

| | | | |
|---|---|---|---|
| 138 | <0.002 percent | 149 | <0.005 percent |
| 139 | <0.02 percent | 151 | <0.002 percent |
| 140 | <0.004 percent | 152 | <0.002 percent |
| 141 | <0.01 percent | 153 | <0.002 percent |
| 147 | <0.01 percent | 154 | <0.002 percent |

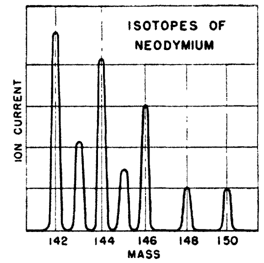

FIG. 1. A typical recorder curve for neodymium. For clarity the mass numbers shown are those of the neodymium isotopes and are sixteen units less than those of the NdO+ ions actually recorded.

The high limits at masses 139 and 141 are due to lanthanum and praseodymium impurities in the neodymium sample. The fact that the small ion currents observed at these masses were not due to Nd isotopes was proved by the observation that the ratios of these ion currents to those of the neodymium isotopes varied with time. Assuming a packing fraction of $-2.7\times10^{-4}$ and a conversion factor of 1.000275, the chemical atomic weight is 144.25, which is in good agreement with the international chemical value of 144.27.

[1] Inghram, Hayden, and Hess, Phys. Rev. **72**, 967 (1947).
[2] Inghram, Hess, and Hayden, Phys. Rev. **73**, 180 (1948).
[3] J. G. Aston, Phil. Mag. **49**, 1191 (1925).
[4] J. G. Aston, Nature **132**, 930 (1933).
[5] A. J. Dempster, Phys. Rev. **51**, 589 (1937).
[6] Mattauch and Hauk, Naturwiss. **25**, 780 (1937).

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## Beta- and Gamma-Spectra of $Cs^{137}$

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AN investigation in this laboratory on the absorption of gamma-rays called for the use of radioactive isotopes emitting monoenergetic gamma-rays. Among those used was $Cs^{137}$, a fission product of high specific activity, produced by the Clinton Laboratories at Oak Ridge, Tennessee. According to the Radioactive Iostope List issued by the Atomic Energy Commission (September 1947), $Cs^{137}$ emits two groups of beta-rays with maximum energy of 0.84 Mev (50 percent) and 0.5 Mev (50 percent), respectively, and one gamma-ray of energy 0.75 Mev. These values were determined by absorption methods. It was considered advisable to investigate the radiations emitted by means of beta-ray spectrographs to check these results.

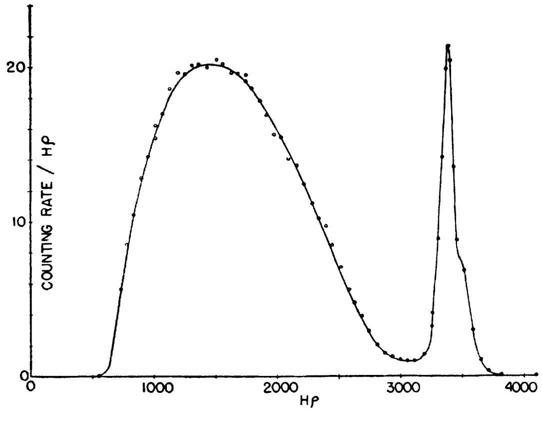

FIG. 1. $Cs^{137}$ β-ray spectrum.

Two beta-ray spectrographs were used: a thin magnetic lens spectrograph and a small 180° spectrograph. The spectrographs had been previously calibrated by measurements of the spectra of ThB, $P^{32}$, and $Cu^{64}$. (In the case of the small 180° spectrograph the magnetic field was also directly measured.)

In order to remove any possible rare earth impurities from the source material, a fluoride precipitation was carried out. The beta-source was a deposit about 2 mg/cm$^2$ thick on a mica backing about 1 mg/cm$^2$ thick.

The beta-ray spectrum is shown in Fig. 1. The shape suggests a beta-spectrum of a simple type on which is superposed at the high energy end a strong internal conversion line. A Kurie plot is reproduced in Fig. 2. It indicates a maximum energy of 0.550±0.005 Mev for the beta-ray spectrum. The linearity of the Kurie plot, above 0.1 Mev, indicates that we have but one beta-ray group. (The departure from linearity below 0.1 Mev is due to the fact that no great pains were taken to use very thin supports or very thin windows.) In particular, we find no indication of a beta-ray group with a maximum energy

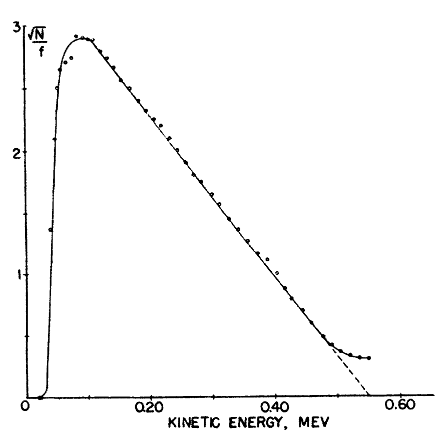

FIG. 2. Kurie plot from Fig. 1.

above 0.55 Mev, as was implied by the absorption measurements referred to. It is believed that absorption methods cannot easily distinguish between a single beta-ray group, on which there is superposed near the high energy end an internal conversion line, and two beta-ray groups.

The internal conversion line has an energy of 0.626 Mev. Adding to this, 0.037 Mev, the binding energy of the $K$ shell for Ba, we find for the energy of the converted gamma-ray 0.663±0.006 Mev. A direct measurement of the gamma-ray energy was made by placing a radiator of lead 0.2 mm thick in front of a sample of $Cs^{137}$ and measuring the energy of the photoelectrons ejected. On adding 0.088 Mev, the binding energy of the $K$ shell in lead to the measured photoelectron energy 0.577 Mev, we obtain for the energy of the gamma-ray 0.665 Mev. No evidence for the presence of any other gamma-ray could be found. The internal conversion coefficient was found to be 0.12.

In summary, this investigation shows that the radiation from $Cs^{137}$ consists of a simple beta-ray spectrum with an end point at 0.550-Mev energy and a single gamma-ray of 0.663-Mev energy, 12 percent of the gamma-ray being internally converted. The monoenergetic nature of the gamma-ray combined with the long half-life of $Cs^{137}$, 33 years, suggests its use as a gamma-ray standard. Coincidence studies are being made to secure information as to the decay scheme of this isotope. The work was carried out under contract with the Office of Naval Research.

## Alkali Halide Scintillation Counters

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It has been shown by J. W. Coltman, H. Kallman, M. Deutsch, and G. B. Collins[1] that beta-particles and gamma-rays can be detected by the scintillations which these ionizing radiations produce in certain crystals. Among the most successful for practical applications are naphthalene and perhaps anthracene.[2] Such crystals are not particularly suitable for many purposes since their densities are small (about 1 g/cc), their atomic numbers low, and their light flashes are small, so that the photomultiplier detector must be cooled to reduce background noise pulses.

Fig. 1. Oscilloscope screen photographs taken at random for 1/30 second. Above, pulses due to NaI(Tl) and below, pulses due to naphthalene under identical circumstances. Sweep calibration: total length of sweep equals 4.3 microseconds.

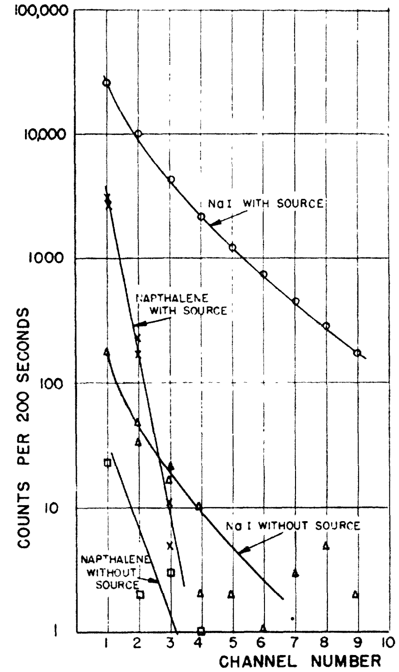

Fig. 2. Differential bias curves for pulses from NaI(Tl) and naphthalene. Channel 1 records pulses in the range 5–10 volts. Channel 2, 10–15 volts, etc.

From the known properties of the alkali halide phosphors[3] it occurred to the author that these materials, of moderate density (2.0 to 4.5 g/cc), medium atomic numbers, great transparency, and beautiful form, might be very suitable for scintillation counters. The time during which light flashes are emitted is also known to be small, although phosphorescence is observed in some specimens.[4]

The author had in his possession a crystal of potassium iodide with a small thallium impurity (probably 0.1 percent or so) which was kindly provided him a year ago by Mr. Frank B. Quinlan of the General Electric Company. This crystal had been grown in 1938 by Dr. Frederick Seitz and Mr. Quinlan. Accordingly, the author, with the help of Mr. J. C. D. Milton, made an attempt to detect gamma-rays with this crystal and a 931A type photo-multiplier. The attempt was successful and will be described at a later time.

Since potassium is radioactive and, moreover, since the pulses observed in KI were somewhat smaller than those observed with naphthalene samples, the author prepared some powder samples of NaI plus thallium. The results were very encouraging, for pulses caused by alpha-particles were equal, if not greater, than those observed with ZnS (silver), which is known to be a very efficient phosphor. The powder sample proved to be hydroscopic when exexposed to air and, in addition, a yellow film formed on the surface. In a few hours the pulses due to alpha-particles were considerably smaller than the original ones.