The Isotopic Constitution of Gadolinium, Dysprosium, Erbium and Ytterbium

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The mass spectra of four rare earth elements have been photographed, by the use of a spark source for the ions. New faint isotopes have been found in all four. The mass numbers of the new isotopes and rough estimates of their abundance in percent are: Gd, 154 (1.5), 152 (0.2); Dy, 160 (1.5), 158 (0.1); Er, 164 (2), 162 (0.25); Yb, 170 (2), 168 (0.06).

THE isotopic constitution of all the rare earth elements has been examined by Dr. Aston[1] with anode rays.[2] The author has also photographed the mass spectra of cerium[3] and neodymium[4] and found in each of these elements two new faint isotopes that had not been observed by Aston. In samarium[4] no new isotopes were found.

The source of the neodymium ions was a spark between electrodes of the metal itself, and for cerium ions the spark was passed between electrodes made by packing nickel tubes with a mixture of the oxide and magnesium and aluminium powder. It was suggested by Hönigschmid[5] that the existence of two new isotopes at 148 and 150 might remove the discrepancy between his value of the atomic weight of neodymium 144.27 and Aston's mean value 143.5, but a measurement of their intensity by Mattauch and Hauk[6] showed they could account for only a part of the discrepancy. The remainder is removed if we take new values determined by them for the abundance of the strong components in place of those obtained by Dr. Aston.

Recently the attention of the author has been called to the possible existence of faint isotopes in other rare earth elements by Dr. Pool. His experiments on the radioactivity induced in these elements by fast neutrons[7] show that at least three new stable rare earth nuclei should exist, and it was thought desirable to examine the even numbered rare earth elements for possible faint isotopes. The stable atomic nuclei now appear to be bounded by radioactive forms, and it is thus of greater interest to complete the list of stable isotopes.

The mass spectrograph has been previously described.[8, 9] Dr. Pool kindly supplied a few milligrams of the oxides of the three elements Gd, Er, Yb from the samples used by him in his experiments. The electrodes were made by packing nickel tubes about one millimeter in diameter with the oxide mixed with a reducing agent. In these experiments, the reducing agent was either calcium, lanthanum or neodymium metal in the form of small filings. The heats of combination[10] are, for La_2O_3, 457 calories; for Nd_2O_3, 435 calories; for 3CaO, 456 calories. For the other rare earths, the values are apparently unknown. It was found that with lanthanum or neodymium as reducers, the spectra were several times as intense as with calcium. It was found that the oxides of the reducing agents appeared faintly, and with Gd, Dy, and Er, the oxides of neodymium could have been confused with their isotopes. In these cases, lanthanum or calcium was also used to reduce the oxides.

GADOLINIUM

Gadolinium oxide was first reduced with neodymium metal. A new isotope at mass 154 was observed on four photographs with exposures of ten to seventy minutes, and an isotope at 152 on two plates with seventy minutes exposure. A second series was made in which the oxide was reduced by lanthanum metal. Here the mass

[1] F. W. Aston, Phil. Mag. **47**, 385 (1924); **49**, 1191 (1925).
[2] F. W. Aston, *Mass Spectra and Isotopes*, (1933) p. 65, 127.
[3] A. J. Dempster, Phys. Rev. **49**, 947 (1936).
[4] A. J. Dempster, Phys. Rev. **51**, 289 (1937).
[5] O. Hönigschmid, Naturwiss. **25**, 701 (1937).
[6] J. Mattauch and V. Hauk, Naturwiss. **25**, 781 (1937).
[7] M. L. Pool and L. L. Quill, Phys. Rev. **53**, 437 (1938).
[8] A. J. Dempster, Proc. Am. Phil. Soc. **75**, 762 (1935).
[9] A. J. Dempster, Rev. Sci. Inst. **7**, 46 (1936).
[10] Bichowsky and Rossini, *Thermochemistry* (1936).

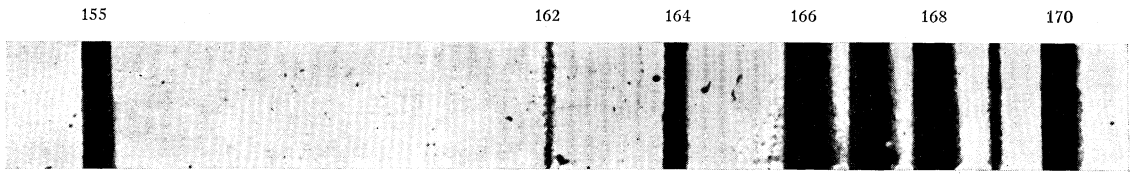

FIG. 1. Mass spectrum of erbium showing two new isotopes at 164 and 162. The mass at 169 is ascribed to thulium present as an impurity (about $\frac{1}{2}$ percent). The mass at 155 is due to lanthanum oxide. The lines due to the strong components are broadened because of excessive over-exposure.

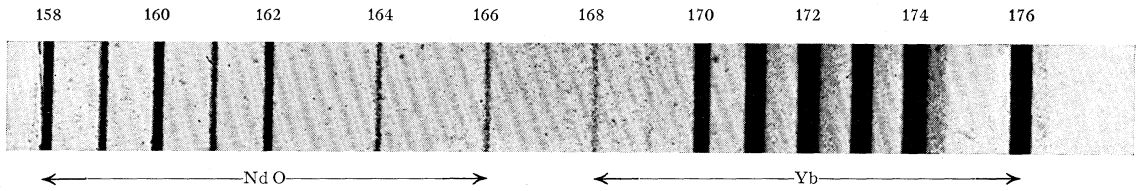

FIG. 2. Mass spectrum of ytterbium showing two new isotopes at 170 and 168. The lighter masses 166, 164, 162, etc. are due to neodymium oxide.

at 154 was observed on thirteen photographs with exposures ranging from half a minute to twenty minutes and the mass at 152 was observed on four with exposures of six to twenty minutes. From the series of photographs with different exposure times, it was estimated that the abundance of the new isotope at 154 was approximately 1.5 percent of the total and that the isotope at 152 was 0.2 percent of the total. The photographs also showed two europium lines at 151 and 153 with about the same intensity as the weakest gadolinium isotope at 152.

DYSPROSIUM

Two different samples of dysprosium oxide were used and reduced with lanthanum. In addition, one was reduced with calcium. Both samples showed two new isotopes at masses 160 and 158. One sample also showed strong lines at 165 and 159 due to holmium and terbium. With the second sample, these lines were much weaker. The isotope at 160 was found on 12 photographs with exposures from one-half to forty minutes, the one at 158 on 4 photographs. From the exposure times, it was estimated that the isotope at 160 makes up about 1.5 percent of the total, and the one at 158, 0.1 percent. In the second sample which was kindly supplied by Professor Quill, the holmium was estimated at 0.4 percent and the terbium at 0.2 percent. No line was observed at 166.

ERBIUM

Two new isotopes were also observed in erbium reduced with lanthanum at masses 164 and 162, the first on eleven photographs with exposures of ten seconds to twenty minutes and the second on four photographs with seven to twenty minutes' exposure. An example of the mass spectrum is given in Fig. 1. The abundances were estimated as approximately 2 percent for the mass at 164 and 0.25 percent for the mass at 162. The spectra also show a faint line at 169 (0.5 percent) which was ascribed to thulium. No other isotopes were observed as strong as 0.03 percent.

YTTERBIUM

The ytterbium oxide was reduced by neodymium and also showed two new isotopes at masses 170 and 168. The heaviest of the faint neodymium oxides came at 166. A spectrum is shown in Fig. 2. The mass at 170 was found on eight exposures of 20 seconds to 80 minutes, and the isotope at mass 168 on two exposures of 60 and 80 minutes. The abundances were estimated at 2.0 percent and 0.06 percent. Faint lines at 175 and 169 were ascribed to lutecium and thulium (<0.03 percent).

The thanks of the author are due to Professor M. L. Pool and Professor L. L. Quill for kindly supplying samples of the rare earth elements for use in the investigation, and to Dr. A. E. Shaw for assistance in preparing electrodes.

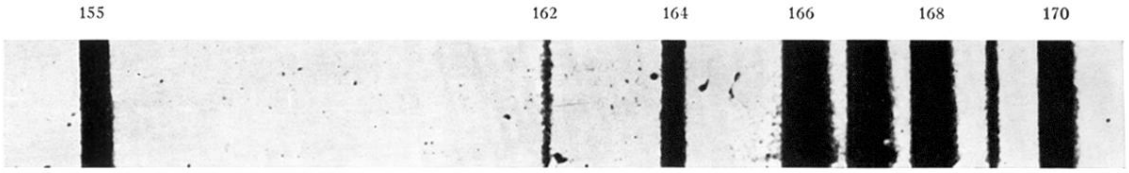

FIG. 1. Mass spectrum of erbium showing two new isotopes at 164 and 162. The mass at 169 is ascribed to thulium present as an impurity (about ½ percent). The mass at 155 is due to lanthanum oxide. The lines due to the strong components are broadened because of excessive over-exposure.

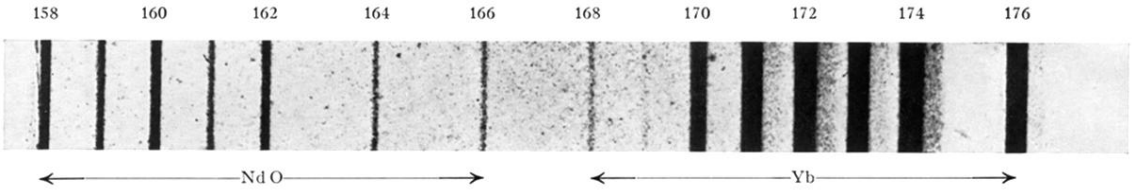

FIG. 2. Mass spectrum of ytterbium showing two new isotopes at 170 and 168. The lighter masses 166, 164, 162, etc. are due to neodymium oxide.