The Relative Abundances of the Zinc and Cadmium Isotopes

WALLACE T. LELAND AND ALFRED O. NIER
Department of Physics, University of Minnesota, Minneapolis, Minnesota

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TWELVE years ago one of us[1] reported values for the relative abundances of the zinc and cadmium isotopes. Since that time numerous improvements have been made in mass spectrometry. Thus, in view of the present-day interest in more accurate nuclear constants it appeared worth while to repeat some of the early work. In the new work we employed a 60° mass spectrometer similar to one already described.[2] Compounds having a negligible vapor pressure at ordinary temperatures could be volatilized by a small oven built into the ion source.

In the investigation of zinc, ZnI_2 was employed and measurements were made for the ZnI_2^+, ZnI^+, and Zn^+ ions. Although the fractional spread in masses varied from approximately 2 percent for ZnI_2^+ ions to 10 percent for Zn^+ ions, no systematic differences in the abundance ratios in the three positions could be observed, so it could be concluded that any discriminatory effects in the instrument were negligible. Table I shows the results obtained.

TABLE I. Isotopes of zinc.

	Mass number				
% Abundance	64	66	67	68	70
Present work	48.89	27.81	4.07	18.61	0.620
Earlier work[a]	50.9	27.3	3.9	17.4	0.5

[a] See reference 1.

The numbers given are the averages for the ZnI_2^+, ZnI^+, and Zn^+ spectra, each weighted equally. The calibrations and consistency of the results lead us to believe that the abundance ratio of any pair of isotopes is accurate to within one percent. With a packing fraction of −7.0 and a conversion factor of 1.000275 in going from the atomic to the chemical scale a chemical atomic weight of 65.40 is computed. This is to be compared with the chemical value 65.38.

In cadmium, ions CdI_2^+, CdI^+, and Cd^+ were investigated. Table II gives the results. As in zinc the numbers given are the averages found for the three types of ions. Here, too, we believe any discriminatory effects to be sufficiently small to state that the abundance ratio of any pair of isotopes is accurate within one percent. A packing fraction of −6.0 yields a chemical atomic weight of 112.42, which is to be compared with the chemically determined value 112.41.

TABLE II. Isotopes of cadmium.

	Mass number							
% Abundance	106	108	110	111	112	113	114	116
Present work	1.215	0.875	12.39	12.75	24.07	12.26	28.86	7.58
Earlier work[a]	1.4	1.0	12.8	13.0	24.2	12.3	28.0	7.3

[a] See reference 1.

These data indicate that the mass spectrometer as employed in the early work must have discriminated against ions of different mass sufficiently to give an error as large as 20 percent in the abundance ratio of the most widely separated isotopes of zinc and cadmium. That an error should have existed is perhaps not surprising since the primary purpose in the earlier work was to obtain very high resolution so that rare isotopes could be detected. Thus extremely narrow slits were employed. As we now know, these conditions can lead to abnormal discrimination.

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The Isotopic Composition of Xenon

A. H. W. ATEN, JR.
Institute for Nuclear Research, Amsterdam, Holland

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WEFELMEIER, in a paper on the exceptional relations between the nuclei of samarium,[1] pointed out that the proportion in which the isotopes of xenon occur is abnormal, too. He suggested that this irregularity should be explained by a transition of four xenon isotopes to tellurium either during or shortly after the formation of our present atomic nuclei. However, we are now in a position to understand that the peculiar situation in xenon has a much more trivial cause.

It is a well-known fact that nuclei with even atomic weight are found in nature in larger concentrations than nuclei with odd atomic weight, because of the difference in binding energy between these two types of nuclei. Thus, if in one element three isotopes occur with consecutive mass numbers—two even ones and one odd one—the concentration of the odd one is always less than the sum of the concentrations of the even ones. The only exception—and a very striking one—is xenon, where Xe^{129} is more than four times as frequent as its two neighboring isotopes together. In this element the percentages of the isotopes have been observed as follows:[2] Xe^{124}:0.094 percent; Xe^{126}:0.088 percent; Xe^{128}:1.90 percent; Xe^{129}:26.23 percent; Xe^{130}:4.07 percent; Xe^{131}:21.17 percent; Xe^{132}:26.96 percent; Xe^{134}:10.54 percent; Xe^{136}:8.95 percent. It is evident from these figures that everything would be normal if the concentration of Xe^{129} were about ten times smaller.

It has repeatedly been pointed out that by far the larger part of the noble gases, which originally accompanied the material of the earth, have been lost from our atmosphere, probably during the earliest part of its history.[3] This theory explains the insignificant quantities of the other noble gases compared with argon. At present this element consists almost entirely of A^{40}, the isotope which was formed by K-capture in K^{40} after most of the original noble gases had disappeared.[4]

Recently Katcoff[5] has shown that I^{129} has an exceedingly long half-life, at least of the order of 10^7 years, unless its beta-rays should be too weak to be detected. Originally, according to a general rule[6] it must have been about as frequent as the stable isotope I^{127}. If the half-life of I^{129} is as long as about 2.10^8 years, demonstrable traces of this isotope must still exist. Indications, though no definite proof, of this fact were indeed obtained by Katcoff.

After the concentration of the original xenon in our atmosphere had fallen to its present low value, the Xe^{129} formed by beta-emission from the I^{129}—which at that time had a much higher concentration—in the iodine of the earth's outer crust and of the ocean, mixed with the small rest of the original xenon. This was sufficient to give to this single isotope its abnormally high concentration.

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On the Use of the Kurie Plot

F. N. D. Kurie
Department of Physics, Washington University, St. Louis, Missouri*

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THERE have been a number of examples in recent literature where, in the mind of this author, the Kurie plot has been somewhat overzealously applied. The method was originally suggested by Kurie, Richardson, and Paxton[1] as a method of examining experimental data for their compliance with either the Fermi or the Konopinski-Uhlenbeck theory of β-decay. In applying the method to data, which we now know to be poor, they found a number of cases (Cl^{38}, K^{42}) in which deviations between theory and experiment were very wide. They showed that, by assuming that these substances emitted two groups of β-particles, a closer consonance between theory and data was obtained.

Because of the continuous distribution of the energy of β-particles there is no straightforward experimental method of ascertaining whether a β-spectrum represents a single β-transition or several. Because of this the Kurie plot has been widely used to aid in this examination. If it were clearly established that a simple spectrum was represented in detail by the Fermi theory, this method of plotting would be a very powerful tool, because, in principle, it is capable of disentangling a complex spectrum to give the upper limits and intensities of all its components. However, at the present stage, the application of the Kurie plot for this purpose is always suspect, since there is no case where the plot is linear down to low energies. Konopinski[2] has given a good summary of the existing data and has pointed out that in the particularly careful work of Lawson and Cork on In^{114} and of Tyler on Cu^{64} there are deviations from the linear Kurie plot below energies corresponding to between ⅓ and ½ of the maximum energy. Thus, even in the most painstaking work and for allowed transitions, agreement between theory and experiment seems to be good only near the upper limit of the β-spectrum. There appears to be no case in which even so optimistic a statement can be made for forbidden spectra.

It is not proposed that the Kurie plot method be abandoned, for there is no other method available for examining a spectrum for complexity. Rather, it is proposed that an argument based on such plots *alone* is not sufficient to establish complexity, and that upper limit values of the lower energy β-particles, derived from such an analysis, should be accepted with some scepticism.

On the other hand, if the Kurie plot gives evidence of complexity, and if there is demonstrated the existence of gamma-rays of energies nearly equaling the differences of these upper limits, and if coincidence counting gives data consistent with the implied complexity, then there is strong evidence in favor of the disintegration scheme proposed.

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Achromatization of Debye-Scherrer Lines*

H. Ekstein and S. Siegel
Armour Research Foundation, Chicago, Illinois

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THE ultimate limit of precision in lattice parameter measurements by the Debye-Scherrer method is given by the spectral width of the primary characteristic radiation, which causes an irreducible width of the line even with an infinitely narrow collimator.** The line could be sharpened by monochromatization of the primary beam, but the elimination of all but a small fraction of the spectral band of a characteristic line would result in a prohibitive loss of intensity.

One can sharpen the diffraction line by achromatizing the characteristic radiation, i.e., by causing all rays of wave-lengths belonging to a spectral line to converge to a focus after diffraction. In Fig. 1 a point source of x-rays, A, radiates a polychromatic beam toward the crystal $QTUR$ so that the central ray AC satisfies the Bragg condition for diffraction by the lattice plane dd' and for the most intense wave-length λ of the spectral band. After diffraction the rays diverge from an apparent source A' so that every ray has only one definite wave-length. A polycrystalline sample P is mounted normal to the central ray $A'E$. All rays diffracted by P will come to a focus N. The distance $CE=V$ is given by

$$V=F\left(1+2\frac{\tan\theta}{\tan\theta_m}\right)\left(-\frac{1}{\cos 2\theta}\right)+l\frac{\cos(\theta_m+\alpha)}{\cos(\theta_m-\alpha)},$$

where $F=NE$, $l=AC$, $\theta_m=\sphericalangle ACd$, θ is the Bragg angle