minima are restored by the addition of sulphur dioxide or stannous chloride. These are the only oxidizing and reducing agents which have been tried. All reagents used gave negative tests for H85.

These investigations have been under way since the middle of the past summer. More recently they have been repeated and extended by one of us (F.A.) in a somewhat more precise manner, while the chemical investigations have been carried on by two of us (E.R.B. and A.L.S.).

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April 3, 1931.

The Principle of Continuity and Regularity of Series of Atom Nuclei (Atomic Species)

While what may now be called the principle of continuity and regularity of the series of atomic species, has been used by the writer in the prediction of isotopes, and has been presented in the form of diagrams for 10 years, the complexity of the diagrams seems to have prevented the recognition of this principle by others. It therefore seems important to give a name to the principle and to illustrate it by simple drawings.

The first figure is taken, with five minor changes which do not affect the general pattern, from a diagram of the helium-thorium series which was used to predict numerous isotopes, most of which have now been found or shown to be probable. The maximum number of isobaric species given in this 1923 figure (J. Franklin Inst. **195,** 554) is 3, as is shown in Fig. 1.

The uranium series (Fig. 2) exhibits at

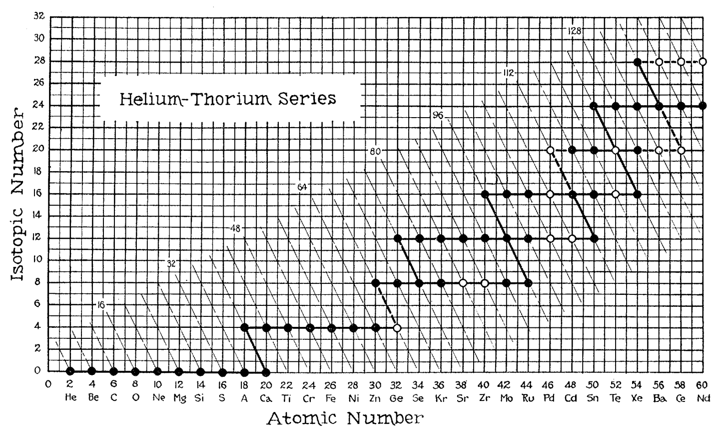

Fig. 1.

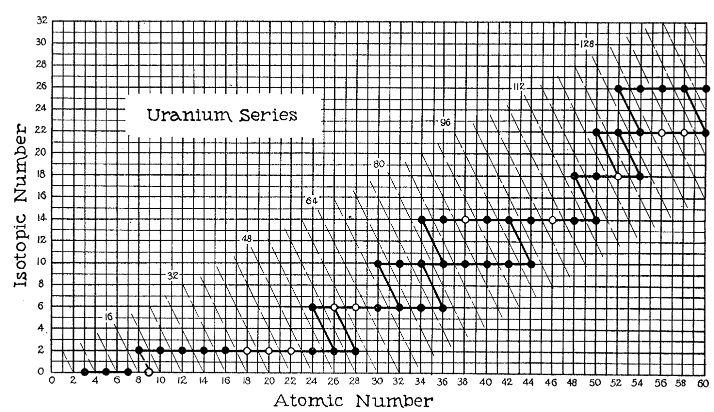

Fig. 2.

present a very simple pattern. The atomic masses (diagonal lines) for both the uranium ($4n+2$) and the thorium ($4n$) series are even, and the general increment of isotopic number or atomic mass between levels in either series is 4, which represents an increment of 2 in the number of cementing or β-electrons. Among the non-radioactive elements a single isotopic number in no case represents species of both the atomic number. The minor differences are explained by other relations presented earlier. These cannot be discussed, on account of lack of space, except that it may be stated that the fact that species of isotopic number 3 are not as yet found in the lithium series, but are found in the beryllium series, is in accord with these relations. These two series thus occupy odd isotopic lines in common, and the

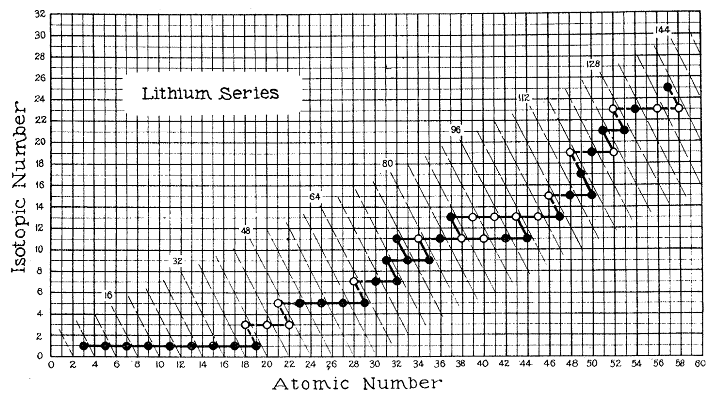

Fig. 3.

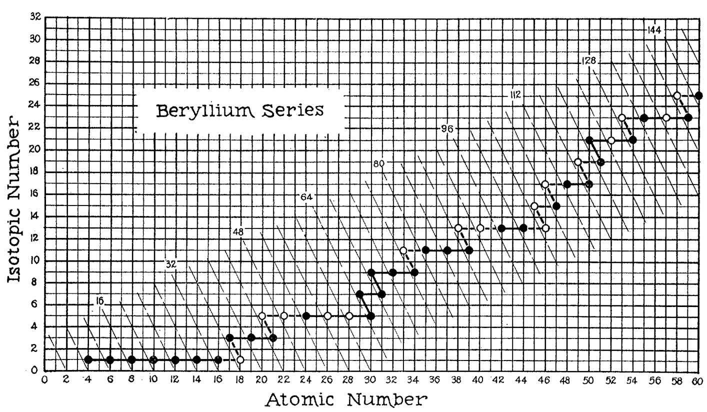

Fig. 4.

series, with the exception of three species of the uranium series on the base line, of the writer's class 4, which have the isotopic number zero, which is normally that of the helium-thorium series. Here a fluorine isotope of mass 18 is indicated as probable.

The $4n+3$ or lithium series (Fig. 3), and the $4n+1$ or beryllium series (Fig. 4) represent odd atomic weights, and the two patterns are made almost identical if the lithium series is plotted with $Z+1$ as abscissae, where Z is general increment in isotopic number in either series is 2.

If the lithium and beryllium series together are considered as a single or "odd" series, very simple relations are exhibited, or the principle of continuity and regularity still holds. Along a given isotopic line the increment of atomic number is one, of atomic mass 2, and of number of electrons, one. Thus the common increment is represented by the formula p_2e in which p represents a proton and e an electron.

This corresponds to an increment of a half alpha-particle. Thus for isotopic number 1 every atomic number from 3 to 17 represents a known species of the combined series.

The fact that the number of superposed levels in each of the even helium and uranium series is larger than in the odd lithium series is in accord with the relation (Proc. Nat. Acad. **2,** 216 (1916) and later papers) that higher nuclear stability is found in general for even than for odd nuclear charge. The smaller number of levels in the beryllium series is in accord with the even more general rule (J. Am. Chem. Soc. **39,** 859 (1917), **42,** 1991–2 (1920) that the electrons in atom nuclei are in general associated in pairs, and an odd number of electrons gives to a nucleus a relatively low stability as compared with that associated with adjacent even numbers, since the beryllium series is the only one in which the number of nuclear electrons is odd, when the atomic number is even (except the class 4 species of Li, B, and N).

The diagonal lines in the charts give the atomic masses. While chlorine of isotopic number 5 and atomic weight 39 is indicated as already discovered, the discovery is not as yet confirmed.

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University of Chicago,
April 9, 1931.

Anomalies in Hyperfine Structures

In a recently published paper Goudsmit[1] points out that the empirically observed hyperfine structure patterns show in some cases very marked deviations from theoretically expected relationships. The discrepancy is observed in the region of high atomic numbers and is usually such as to make it necessary to ascribe an anomalously large separation to the $p_{1/2}$ term of the single electron spectrum. The interval rule appears to be obeyed in the case of Bi rather accurately. It is logical therefore to look for an explanation in the manner in which the $p_{1/2}$ and $p_{3/2}$ states interact with the nucleus.

Dirac's equation shows in fact that such a difference is to be expected. A calculation exactly similar to the one made by the writer[2] for s terms shows that $\overline{(r^{-3})}$ of the ordinary formulas for $p_{1/2}$, $p_{3/2}$ must be replaced by $(2\pi/\Lambda)I, -(4\pi/\Lambda)I$, $I=\int\phi_1\phi_2 r^{-2}dr$. Here ϕ_1, ϕ_2 are the two radial functions of Dirac-Gordon (denoted by Gordon as ψ_1, ψ_2). The normalizing factor is chosen so as to have $\int(\phi_1^2+\phi_2^2)dr=1$. In the neighborhood of the nucleus the "term-value energy" and screening

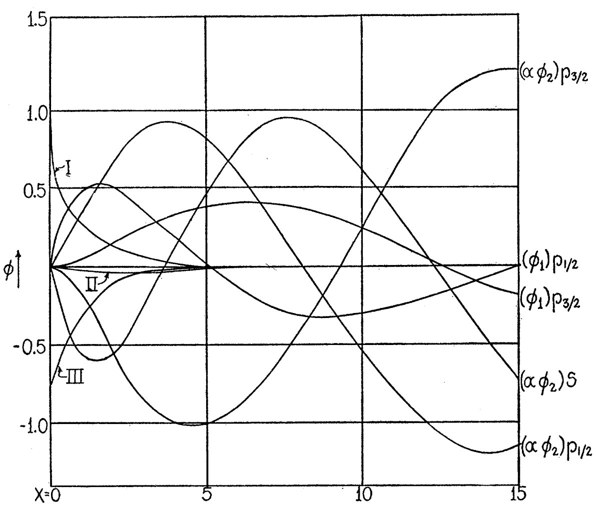

Fig. 1. I is $\phi_1\phi_2/x^2$ for $P_{\frac{1}{2}}$. II is $\phi_1\phi_2 x^2$ for $P_{3/2}$. III is $\phi_1\phi_2 x^2$ for s.

[1] S. Goudsmit, Phys. Rev. **37,** 663 (1931).
[2] G. Breit, Phys. Rev. **35,** 1447 (1930).