Wentzel's criterion for single scattering was roughly approximated.

The ratio of scattered to incident intensity, for the effective thickness of the foil at 45° incidence, *viz.*, 8.40 $\times 10^{-6}$ cm, was $8.92 \times 10^{-6}$. Our probable error is believed to be 15 percent.

Our observed scattering is 0.97 of that predicted by Mott, thus differing from that of other observers who, without such rigorous exclusion of retarded electrons, have observed a considerably greater ratio.

We are grateful to Dr. F. E. Myers and Dr. J. F. Byrne for the accelerating equipment and for other assistance, to Dr. O. Halpern for helpful discussion, and to Mr. A. C. Weid for assistance in taking observations.

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[1] E. G. Dymond, Proc. Roy. Soc. **A145**, 657 (1934).
[2] N. F. Mott, Proc. Roy. Soc. **A135**, 429 (1932).

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## An Explanation of the Relative Stabilities of Isotopes of the Lighter Elements

As is well known[1] the mass and charge of any isotope of the lighter elements may be expressed, in the case of atoms of even atomic number, as $n$ alpha-particles plus zero, one, two or three neutrons; and for atoms of odd atomic number, as $n$ alpha-particles plus $H_1^1$, $H_1^2$, $H_1^3$ or $H_1^4$. For any given element the existence or nonexistence of all four of these possible isotopes has always been a puzzling problem. The following approximate calculations will show that the solution is surprisingly simple and that it is possible to state with certainty which isotopes are stable.

To make these calculations the experimental energy relations, in terms of atomic weights,[2] between the neutron and the hydrogen isotopes will be used. The assumption will be made that the energies of $H_1^1$, $H_1^2$ and $H_1^3$ remain approximately constant when these groups exist in combination with alpha-particles in heavier nuclei and the problem will be to determine the effect of the nuclear charge upon the transition of hydrogen into neutrons or helium by the emission of positrons or electrons. As an approximation for the coulombic field energy, or field mass, of each nucleus, the classical expression[3] $M_F = \frac{2}{3}Z^2/R$ will be used, where $Z$ is the atomic number and $R$ the nuclear radius. For the latter the best experimental determinations agree well with the equation of Dunning[4] $R = 1.315 \times 10^{-13} \sqrt[3]{\text{at. wt.}}$ If we know $Z$ and $R$ the value of $M_F$ may be calculated for each nucleus and $\Delta M_F$ for nuclear reactions. The emission of $e^+$ reduces $M_F$ and thus $\Delta M_F$ is negative for such a process while the emission of $e^-$ increases $M_F$ and $\Delta M_F$ is correspondingly positive. The following calculations may now be made:

*Type* $n\alpha + n_0^1$ *and* $n\alpha + H_1^1$. For the reaction $H_1^1 = n_0^1 + e^+$, the total change in mass, $\Delta M$, is 0.002 mass unit. For the reaction $Li_3^5 = He_2^5 + e^+$, $\Delta M_F = -0.002$ but for $B_5^9 = Be_4^9 + e^+$, $\Delta M_F = -0.003$ and $\Delta M_F$ becomes more negative for higher atomic numbers. The decrease in coulombic energy is then sufficient to cause positron emission from all nuclei of the $n\alpha + H_1^1$ type, with the possible exception of $Li_3^5$. Hence $B^9$, $N^{13} \cdots K^{37}$ should not exist but all isotopes of the type $Be^9$, $C^{13}$, $O^{17}$ should be stable.

*Type* $n\alpha + 2n_0^1$ *and* $n\alpha + H_1^2$. For the reaction $H_1^2 = 2n_0^1 + e^+$, $\Delta M$ is 0.0045. For the reaction $N_7^{14} = C_6^{14} + e^+$, $\Delta M_F = -0.004$ and for the reaction $F_9^{18} = O_8^{18} + e^+$, $\Delta M_F = -0.005$. Hence $N^{14}$ and similar nuclei of lower odd atomic numbers should be stable, i.e., $Li^6$ and $B^{10}$ but $He^6$ and $Be^{10}$ should be unstable. Likewise $F^{18}Na^{22} \cdots K^{38}$ are unstable and $O^{18}Ne^{22} \cdots A^{38}$ are stable.

*Type* $n\alpha + 3n_0^1$ *and* $n\alpha + H_1^3$. For the reaction $H_1^3 = 3n_0^1 + e^+$, $\Delta M$ is 0.010. For the reaction $K_{19}^{39} = A_{18}^{39} + e^+$, $\Delta M_F$ is $-0.008$. Hence the coulombic energy is not sufficient to cause $e^+$ emission and $K^{39}$ and all lighter isotopes of this type, i.e., $Li^7$, $B^{11} \cdots K^{39}$ are stable and $Be^{11}$, $C^{15} \cdots A^{39}$ unstable. Also, for the reaction $H_1^3 = He_2^3 + e^-$, $\Delta M = 0.000$ and since the $\Delta M_F$ for $e^-$ emission is always positive, isotopes of the type $n\alpha + He_2^3$ should not exist, i.e., $Be^7$, $C^{11}$, $O^{15} \cdots$ are unstable.

*Type* $n\alpha + 4n_0^1$ *and* $n\alpha + H_1^4$. For the reaction, $4n_0^1 = He_2^4 + 2e^-$, $\Delta M = -0.032$. This energy is so large that the coulombic energy is not sufficient for the lighter elements to prevent electron emission from the $n\alpha + 4n_0^1$ type, and no isotopes differing by 4 mass units should exist. For the reaction $H_1^4 = He_2^4 + e^-$, the energy is not known, but it is obviously very highly negative, probably about $-0.015$ and all elements of the $n\alpha + H_1^4$ type, i.e., $Li^8$, $B^{12}$, $N^{16}$, etc. will undergo $\beta$ decomposition.

A summary of the predictions for these various types gives a complete picture of the isotopes of the elements of low atomic numbers. Fortunately the energies are large enough so that the approximate calculations of the coulombic terms give the correct qualitative answer. For heavier elements the composition cannot be simply expressed in terms of $\alpha$-particles. The first exception is $Cl^{37}$, which might be represented at eight alphas plus a hydrogen five or as nine alphas plus a negative proton and for heavier elements the structures become increasingly complex. In the author's theory this may be interpreted as the conversion of a zinc sulfide type of $\alpha$-particle lattice to a diamond lattice of neutrons with the positive charge on the surface particles, and even approximate calculations of the energies can only be made for a few very simple structures.

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[1] Harkins, Chem. Rev. **5**, 371 (1928).
[2] Oliphant, Nature **137**, 396 (1936).
[3] See also Latimer and Libby, J. Chem. Phys. **1**, 133 (1933), and Latimer, J. Am. Chem. Soc. **58**, 1061 (1936).
[4] Dunning, Phys. Rev. **45**, 587 (1934).

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## Erratum: Investigations of the Deuteron-Deuteron Reaction

R. Ladenburg and R. B. Roberts,
*Palmer Physical Laboratory, Princeton, N. J.*
(Phys. Rev. **50**, 1190, 1936)

The last lines of Section 4 should read: "Oliphant, Harteck and Rutherford estimate the yield to be of the order of magnitude of 1 in $10^6$ at 100 kv."