The atoms whose nuclei carry 28 or less positive charges are much more stable than those of higher atomic number. This is illustrated by the relative abundance of such elements as represented by the following table:

TABLE II

Proportion in Various Materials of the Elements of Low Atomic Numbers

Material	Percentage of Elements with Atomic Numbers 1–29	30–92
Meteorites as a whole	99.99	0.01
Stone meteorites	99.98	0.01
Iron meteorites	100.00	0.0
Igneous rocks	99.85	0.15
Shale	99.95	0.05
Sandstone	99.95	0.15
Lithosphere	99.85	0.15

When there are several varieties of atomic nuclei all carrying the same positive charge, as is the case with lead, with 82 positive charges on the nucleus, the nuclei differ in stability, but the complete atoms do not differ in their chemical properties nor in their spectrum. This has been shown very beautifully by Soddy, by Merton, and by Richards and Baxter, but most accurately by Dr. Aronberg, who worked at my suggestion. Two isotopes may have practically the same atomic weights, and differ only in the stability of their nuclei, as I pointed out four years ago.

THE BUILDING OF ATOM NUCLEI AGAIN

Let us now pay attention to the building of nuclei of even numbered charge, since the time is not sufficient to consider those of odd number also. Three, four, five, six, seven, eight or ten alpha particles may unite to form the nucleus of a complex atom, but two alpha particles alone, or more than ten alone, do not make a stable system.

In all heavier atoms there are some alpha particles which are bound on by two negative electrons. Thus the sulphur nucleus is a compound of 8 alpha particles alone, while the argon nucleus contains 10 alpha particles and two negative binding electrons. It is the presence of an extra alpha particle in the argon nucleus which makes its atomic weight higher than that of potassium.

The number of binding electrons does not increase to 4 until element 32 (germanium) is reached, but rises to 26 in the thorium atom. *It is these binding electrons which are given off in the beta disintegrations of the radioactive elements,* and if time permitted it could be shown that this disintegration is exactly in accord with the system of structure proposed for the nuclei of the lighter atoms. For example a radioactive atom may lose five alpha particles in direct succession, but never more than two of the binding electrons. Furthermore, if it loses a single binding electron it always loses a second one, but not more than two, which indicates that, corresponding to our theory, such binding electrons are associated in pairs.

The principal difficulty to be encountered in the artificial disintegration of atoms, that is, in the disintegration of their nuclei, is that of getting sufficient energy into such a small volume as that of a nucleus. In the building of atoms there is the additional difficulty of securing the proper arrangement of the alpha particles to give stability.[3]

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THE DISRUPTION OF ATOMS BY ALPHA RAYS

RECENTLY under the modest title "An Anomalous Effect in Nitrogen,"[1] Rutherford reported the remarkable discovery that when nitrogen molecules are bombarded by alpha rays, penetrating rays with a range of 28 cm. in air are produced which are certainly lighter than nitrogen atoms and which are probably

[3] The details of the system of atom building presented here may be found in the following references: *Journal of the American Chemical Society*, 37, 1367–1421, 1915, 38, 186–214, 1916, 39, 856–879, 1917; 41, 970–992, 1919. *Phil. Mag.*, 30, 723–734, 1915. SCIENCE, N. S., 46, 419–427, 443–448, 1917. *Proc. National Academy of Sciences*, 1, 276, 1915; 2, 216–224, 1916.

[1] *Phil. Mag.*, 37, 581–87, June, 1919; *cf.* SCIENCE, 50, 472, November 21, 1919.

hydrogen rays. His experiments furnish conclusive evidence that by this bombardment, nitrogen atoms may be disrupted and thus transformed or transmuted.

In the paper preceding the one just mentioned, Rutherford describes other secondary rays produced by alpha ray bombardment in both nitrogen and oxygen, which have a range in air of 9 cm. instead of 28 cm. These rays, he states, are presumably swift, singly charged nitrogen and oxygen atoms, respectively. The purpose of this note is merely to point out that their nature may be more interesting than their discoverer suggests.

The conclusion that they may be singly charged atomic rays is based on the fact that the computed ranges for such rays, 9.3 cm. the same as the observed ranges, 9 cm. in each case, whereas doubly charged atomic rays would be expected to have only one fourth these ranges. But the agreement is not very convincing, and there are other reasons for doubting the correctness of the hypothesis.

The alpha-ray experiments practically force us to accept the nuclear atom. In the case of such an atom, is it possible that a singly charged nitrogen ray may be produced as a result of a close collision between an alpha ray and a nitrogen nucleus? I think not; for since a singly charged nitrogen atom is a nucleus with six orbit electrons attached, a singly charged nitrogen ray could be produced only if each of the electrons as well as the nucleus were acted upon by the relatively large force required to give it a speed of about 10^9 cm./sec. in less than 10^{-18} sec. It can easily be computed that the field of the nucleus is insufficient to hold the electrons under these circumstances. Therefore, unless we postulate a stability which ionization phenomena seem to disprove, we must conclude that after such collisions, the orbit electrons are left behind. Moreover, even if singly charged rays were shot out, it is difficult to believe that most of the orbit electrons would not soon be detached as a result of the passage of the rays through many atoms. In other words, various experiments have given us a conception of the structure of atoms which makes it highly improbable that singly charged nitrogen rays would be produced as a result of bombardment by alpha rays.

Now the secondary nitrogen rays can not be multiply charged nitrogen atoms or nuclei, for such rays would have too short a range. And they can not be hydrogen rays because the scintillations they produce are too bright. Therefore they must be fragments of nitrogen nuclei which are larger than hydrogen nuclei. Rutherford has proved, as stated above, that nitrogen nuclei can be disrupted by alpha rays. If we suppose, as seems probable, that the nitrogen nucleus is made up of hydrogen and helium nuclei, then the disruption of the nucleus would be expected to result in both hydrogen and helium rays. It is therefore possible that *the less penetrating secondary rays observed by Rutherford when nitrogen is bombarded are alpha rays produced by the disruption of nitrogen nuclei.* The similar rays observed with oxygen may also be secondary alpha rays originating in disrupted oxygen nuclei. The fact that the scintillations produced by these rays are much like those due to alpha rays of the same range supports this suggestion.

But how is it possible for the range of the secondary alpha rays to be greater than that of the primary rays, in violation of the laws of mechanics? Just as the energy of alpha rays comes from the potential energy released when a radioactive atom becomes unstable, so the rays resulting from the disruption of a nitrogen nucleus may be expected to receive energy as a result of the mutual repulsion of the fragments. If the secondary rays are alpha rays, then, the effect of the bombarding alpha rays must be to make the nuclei unstable, producing an *artificial radioactivity.*

It is believed that the difficulty of explaining why so many of the secondary rays travel in the direction of the bombarding rays is no greater from this point of view than from the other.

It will be extremely interesting to determine by deflection methods the mass and charge of these rays so as to decide whether they are in fact nuclear fragments. In this way we may get definite evidence as to the fundamental structure of nuclei.

G. S. FULCHER
NATIONAL RESEARCH COUNCIL,
November 27, 1919

THE FESTSCHRIFT OF SVANTE ARRHENIUS[1]

Highly Honored Friend and Master:

Modern culture is perhaps best characterized by man's enlarging control over nature. But this has not been attained without an increased knowledge of the forces wherewith nature works. Through your now over thirty year old theory concerning force ions, you have made possible a deeper penetration into nature's own workshop than was formerly attainable. Concerning electrolytic phenomena, which your countryman Berzelius, with correct appreciation of their fundamental significance, so diligently studied, you have shed a wonderful light and you have thereby strengthened the foundations for the whole chemical knowledge and this not alone with respect to lifeless nature, but in equally high degree with respect to living nature. "Selten hat ein glücklicher Gedanke," once said W. Ostwald, who was himself the first to understand its meaning, "in so hohem Maasse Licht über weite und schwierige Gebiete geworfen, wie die von Arrhenius entwickelte Idee, dass die Elektrolyte in wässriger Lösung in ihre Ionen dissoziirt sind."

Briefly stated, you have with your theory stirred up a culture wave within the scientific and technical world which will sweep forward through time and thereby you have also become one of our time's culture bearers.

If one may believe Xenophon, Socrates used to advise those who sought help concerning their difficulties, to carry out that which they knew should happen, as he deemed best; but otherwise he advised that they ought to have recourse to the art of divination, hearken to the inner spirit, which should give them directions. Thus does also the scientist. When theory is clear he follows it in the best manner, but when the opposite is true, even he must resort to divination; and a wonderful prophet you have been. You seem once to have had one of these dreams which, as is said, sometimes goes ahead and anticipates the judgment of clear daylight.

Among the friends of Socrates was also Aristippus. It is related concerning him that he like the rest of beauty-loving Athens was sorely smitten by the handsome Lais. One of his friends expressed surprise over this that even he, the sober philosopher, should have been caught in her net. Aristippus, who was no friend of superfluous words, answered merely: Caught, by no means imprisoned. Thus you can also say concerning the ions. You have bound them to reality by unbreakable bonds, but your spirit for research has not let itself be bound to merely this field of labor.

When one wishes to scale the Alps he comes first to the warm, peaceful valleys where living nature steps forward to meet him in all her beauty, and there one might wish to dwell his whole life were not the view so limited. One climbs higher and higher and the horizon widens, but the air becomes sharper, flowers and foliage disappear, and at last one is met by only the cold blasts of snow and ice. Everything would speak of death if in this indescribable silence, in this boundless heaven there was not found something which spoke of the unending, the everlasting. A similar road you have trodden through the research world. You have with your keen vision imagined yourself to see the whole universe's unending space and everlasting time, how the worlds therein develop and dissolve, how all is a *perpetuum mobile;* yes, you have with the camera's help found how the seeds of life sail through the ether ocean from world to world. Such are the wide-embracing views you have given us.

To celebrate the day when you with yet unbroken power and undiminished interest enter upon your seventh decennium, we have with admiration for your research work and in devoted friendship for your person dedicated to you this writing.

[1] Translation of Preface of "Festskrift utgiven Till Svante Arrhenius' 60–Arsdag den 19 Februari, 1919."