An Experimental Method for the Estimation of the Age of the Elements

HARRISON BROWN
Institute for Nuclear Studies, University of Chicago, Chicago, Illinois
June 28, 1947

ALL evidence indicates that the elements were formed at some time within a period of 3×10^9 to 10×10^9 years ago. The lower limit has been set by estimates of the age of the earth's crust,[1] while the upper limit is based upon the fact that certain radioactive species still exist in nature. Further definition of the age, utilizing well-known radioactive methods of age determination, is difficult primarily because of our ignorance concerning the original isotopic composition of lead. However, recent studies of the composition of meteoritic matter, undertaken by the author, suggest a method for at least partially overcoming this difficulty.

Meteorites are composed in general of mixtures of one or more distinct phases: metallic iron-nickel, silicate, and sulfide. Elements are distributed between the phases according to rules which are as yet incompletely understood. It is generally believed, but not proved, that the elements distributed themselves between these phases during the process of planet formation.

The time elapsed since the formation of the elements can be divided into two parts: t_1, the time interval between the formation of the elements and the separation of elements into the various phases comprising meteoritic matter; and t_2, the time interval between the meteoritic phase separation and the present. The latter time interval, t_2, is subject to experimental determination using the uranium-lead technique.[2] It involves the determination of the isotopic composition of lead isolated both from the silicate and metallic phases, together with a determination of the lead and uranium contents of both phases. Although this is a difficult task, it is by no means impossible, as can be seen by the average abundance figures[3] given in Table I.

A direct estimate of t_1 is possible if we assume that when the elements were formed, essentially all possible species were formed in amounts depending upon nuclear properties such as binding energy and the number and kinds of particles in the nucleus. The short and intermediate-lived substances presumably have since decayed away, while those species with half-lives comparable to the total elapsed time still exist in nature.

If the meteoritic phase separation took place before a given radioactive species had decayed into insignificance, and if the parent and daughter elements were fractionated from one another during the phase separation, then one would expect the isotopic composition of the daughter element to differ in the two phases. In such a case, one would be able to set an upper limit to the time interval of a few half-lives.

On the other hand, if no isotopic composition difference is observed, a lower limit for the interval could be set, although less precisely because of the difficulty of estimating the initial abundance of the parent. If a series of nuclear species, possessing half-lives covering the range of 10^3 to 10^9 years were available, it should be possible to estimate t_1 fairly accurately. Unfortunately, such a series is as yet unknown, probably, in great measure, because of the difficulties of producing these species of intermediate half-life in sufficient intensity to permit their detection and identification. It is possible, however, that with the development of high energy accelerators and high intensity piles more species in this interesting range will be discovered and characterized.

TABLE I. Uranium and lead contents (parts per million).

	Iron phase	Silicate phase	Earth's crust
Uranium	0.1	0.4	4
Lead	56	2	16

The general method outlined above for the determination of t_1 has been applied to one case, that of copper,[4] where unfortunately the half life of the nickel parent (Ni^{63}) is as yet unknown.[5,6] Stability considerations indicate that it should be long lived. No isotopic abundance differences between copper isolated from an iron meteorite and earth's crust copper were observed, although the nickel-copper ratio in the first case is 200 and in the latter approximately unity. This result, when coupled with an identification of the Ni^{63} half-life, should permit a rough estimate of the lower limit of t_1.

[1] A. Holmes, Nature **159**, 127 (1947).
[2] It should be pointed out that Paneth has determined the helium ages of a number of meteorites. F. Paneth, Zeits. f. Elektrochemie **36**, 727 (1930); Naturwiss. **19**, 164 (1931); Zeits. f. physik. Chemie (Bodenstein Festband) **145** (1931).
[3] V. M. Goldschmidt, Mat.-Naturv. Klasse, 1947, No. 4 (Oslo, 1938).
[4] H. Brown and M. G. Inghram, Phys. Rev. **72**, 347 (1947).
[5] J. A. Swartout, *et al.* Phys. Rev. **70**, 232 (1946).
[6] E. E. Conn, *et al.* Phys. Rev. **70**, 768 (1946).

The Effect of a Direct Current Potential on the Initiation of a Radiofrequency Discharge

F. KIRCHNER
University of Cologne, Cologne, Germany
July 5, 1947

IN a recent number of this journal[1] an effect of a d.c. potential on the initiation of a radiofrequency discharge was described by Arthur A. Varela. He found that the application of a d.c. potential greatly impeded the formation of the discharge, and that a considerably higher r-f potential was required for the initiation of the discharge.

I should like to mention that I described the same effect in a paper[2] in which I studied the r-f potentials necessary for the initiation and maintenance of a discharge in different gases with different frequencies. I found, for instance, that the application of a d.c. potential of plus or minus 60 volts to a r-f discharge, maintained by an a.c. potential of 60 volts, caused the discharge to vanish completely.[3] As I showed in this paper, the reason for this effect is that the displacement which the electrons responsible for ionization can attain during one period of the oscillation, is of the same order of magnitude as, or is smaller than, the distance between the electrodes, and that therefore these electrons can oscillate between the electrodes and give rise to a cumulative generation of ions.

[1] A. A. Varela, Phys. Rev. **71**, 124 (1947).
[2] F. Kirchner, Ann. der Physik **77**, 287 (1925).
[3] F. Kirchner, Ann. der Physik **77**, 298 (1925).