knife is kept wet during the process, usually with 65 per cent. to 70 per cent. alcohol. This may conveniently be accomplished by arranging an automatic oil cup so that it will drop the alcohol on the knife at the desired rate. The cutting should be done with a quick, firm motion. If the block has been sufficiently hardened and the knife edge is in good condition every section should be perfect and the thickness of successive sections uniform. A small sable brush is best for handling the sections. The brush is kept wet in the alcohol on the knife and if the sections are to be mounted serially they are arranged near the back of the knife from right to left as they are cut, always keeping them moist. Several rows of the proper length to fit under the cover-glass may be so arranged in the relation to each other which they are to occupy on the slide. A thin piece of tissue paper is placed smoothly over the sections, being sure that there is sufficient alcohol to wet through the paper. With a uniform downward motion the paper is pulled off the knife, preferably over the back. The sections sticking flat to the paper are carried across to a chemically *clean* slip on which the paper is laid reversed so that the first section cut occupies the upper left hand corner and so that the sections are properly centered. The paper may be smoothed out with the addition of a small amount of alcohol if necessary. Several layers of absorbent paper are placed on top and the whole rolled lightly but firmly with some cylindrical object for about ten seconds. This, in addition to pressing the sections tightly against the glass, removes the 70 per cent. alcohol. The paper is then quickly peeled off, leaving the sections on the slide where they are instantly flooded with clove oil, which should remain until the sections are perfectly translucent. The clove oil will dissolve sufficient of the collodion to fasten the sections to the slip; after about eight minutes the surplus oil is drained off and the slide placed in 95 per cent. alcohol. After ten or fifteen minutes it is changed to fresh 95 per cent. alcohol to insure the complete removal of the clove oil. From this point on the preparation is treated the same as if it contained paraffin sections except that the collodion is not removed. Dr. Miriam J. Scott is authority for the statement that some of her slides, so prepared, were kept in 70 per cent. alcohol for two months without the loss of a section. An equally satisfactory method, if properly used, is to smear the surface of the chemically clean slip with a film of Mayer's albumen, place the sections on it as directed above, and, omitting the clove oil, immerse quickly in 95 per cent. alcohol for at least ten minutes. One small drop of Mayer's albumen is sufficient to prepare 25 or 30 slips. Any considerable amount of albumen precipitated under the sections impairs the stain and lessens the probability of the sections remaining on the slip.

Cautions. (1) The block must be sufficiently hard to be quite rigid, otherwise its elasticity will interfere with cutting perfect sections such as are necessary for serial preparations. The proper degree of hardness should be obtained before placing in 70 per cent. alcohol.

(2) The slip must be chemically clean. It may be tested in this respect by placing a drop of distilled water on its surface. It is satisfactory if the water spreads uniformily and does not roll off when the slip is tilted without wetting the glass. (This is the most important of the precautions.)

(3) Just after the sections have been placed on the slide there is a moment when very precise work is necessary. After they are covered with the absorbent paper, they must be rolled long enough to remove practically all of the 70 per cent. alcohol except what is actually in the sections; when this condition has been obtained, speed is necessary in order to remove the paper and get the sections covered with the next medium before air gets between them and the slip, owing to the evaporation of the alcohol which is in the sections.

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SPECIAL ARTICLES

DIRECT EVIDENCE OF ATOM BUILDING[1]

THROUGH new and more precise measurements on cosmic rays than those heretofore made, Millikan and Cameron have just succeeded in bringing forth quantitative evidence that those rays represent the precise amount of energy which should, according to Einstein's equation showing the relation of mass to energy, be emitted in the form of ether waves when the primordial positive and negative electrons unite to create helium atoms and other light atoms such as oxygen and silicon, magnesium and iron.

Millikan and Cameron have investigated these rays through experiments in high mountain lakes, both in California and in Bolivia, and Millikan and Bowen have studied them with the aid of self-recording electroscopes sent up by sounding balloons which reached nine tenths of the way to the top of the earth's atmosphere.

The results obtained in such investigations during the past eight months constitute the first indubitable evidence that the cosmic rays on which they have been experimenting, instead of being spread like white light

[1] A report made in Pasadena to the California Institute Association on March 16.

over a considerable spectral region, consist of bands of definite frequency, or color, like the light from a neon lamp or from a Cooper-Hewitt mercury arc.

The general spectral region, however, in which these bands are found, corresponds to frequencies 100,000,000,000 times greater than those emitted by the aforementioned lamps. This is why these cosmic radiations are powerful enough to penetrate 200 feet down into a mountain lake before they are completely absorbed.

The rays brought to light by this most recent work correspond to four main radiations extending over a spectral region three octaves wide and having frequencies identical with those which are computed theoretically from the loss of mass which would occur in accordance with the foregoing equation of Einstein, first, when the helium atom is created out of the nucleus of the hydrogen atom (the positive electron) two negative electrons acting as the binding agents; second, when oxygen and nitrogen atoms are similarly created out of hydrogen; third, when silicon and magnesium are so produced, and, fourth, when the atom of iron is born.

Hydrogen and helium are extraordinarily abundant gases, while the four elements—oxygen, magnesium, silicon and iron—are the most abundant elements found in meteorites and constitute a not unlike percentage of the earth. The agreement between the observed and computed frequencies is so good as to make it highly improbable that it represents an accidental coincidence.

The quantitative nature of the agreements obtained is illustrated as follows: While the atomic weight of hydrogen is 1.00778, the atomic weight of helium is 4.00054; when helium is created by the union of four hydrogen atoms an amount of matter disappears which is equal to four times 0.00778.

The difference—namely, .03058 grams—must, according to Einstein's equation (MC^2-E), go off in the form of radiant energy when the helium atom is formed, and the appearance of this amount of energy in the form of a monochromatic ether wave would give that ether wave the penetrating power which is represented by an absorption coefficient numerically equal to .305.

This is within a few per cent. of the absorption coefficient directly observed by Millikan and Cameron for the most conspicuous band in their cosmic ray spectrum.

There is, further, a philosophic argument which supports the results of this observation. We have long known that all elements have a structure which indicates that they are exact multiples of the mass of the positive electron, which is the nucleus of the hydrogen atom.

We have also known for thirty years that in the radio-active process the heavier atoms are disintegrating into lighter ones. It is, therefore, to be expected that somewhere in the universe the building-up process is going on to replace the tearing-down process represented by radio activity.

Up to the present, however, no evidence had ever been found that this building-up or creative process is going on now. The present experiments constitute the first discovery of such evidence.

It must be taken with some reserve and must be subjected to further critical analysis and further experimental tests. But, so far as they go, these experiments are at least indications, and the first direct indications, that all about us, either in the stars, the nebulae or in the depths of space, the creative process is going on, and that the cosmic rays which have been studied for the past few years constitute the announcements broadcast through the heavens of the birth of the ordinary elements out of positive and negative electrons.

When it is remembered that the positive electron is the nucleus of the hydrogen atom, and that the spectroscopic survey of the heavens shows the extraordinary abundance everywhere of hydrogen; and when we reflect that we have known for fifteen years that all the elements have weights that are practically exact multiples of the weight of the hydrogen atom as it appears in the structure of helium, the foregoing conclusion that the process of atom-building out of positive and negative electrons (the latter have a mass that is negligible in comparison with the former) is now going on gains additional plausibility.

If it is confirmed it will constitute new proof that this is a changing, dynamic and continuously evolving world instead of a static or a merely disintegrating one.

Further qualitative support for the validity of the foregoing evidence is derived from the fact that so far as we can now see there are no sorts of nuclear changes which could take place powerful enough to produce the observed cosmic rays except those herewith suggested.

Putting together, then, the quantitative and the qualitative evidence, we may have some confidence in the conclusion that the heretofore mysterious cosmic rays, which unceasingly shoot through space in all directions, are the announcements sent out through the ether of the birth of the elements.

R. A. MILLIKAN,
G. H. CAMERON

FORMS AND PROPERTIES OF WATER SOLUBLE PHOSPHORUS IN SOILS

A RECENT publication from this laboratory gave a method for the quantitative determination of organic