to a possible explanation of the tenfold greater abundance of He^3 (as decay product of H^3) in atmospheric helium as compared to gas well helium, and to suggest that radiocarbon might be found in living matter especially in connection with the concentration of C^{13} for tracer uses.

B. HELIUM THREE

It is well established[1-7] that neutron secondaries are produced in the atmosphere by the cosmic radiation. Less well established is the total number Q, of neutrons produced per cm^2 of the earth's surface per sec. The recent paper of Korff and Hammermesh[7] allows a rough estimate of Q to be made. Integration of their curve for neutron production rate per gram *vs.* depth from the top of the atmosphere gives Q as 0.8 neutrons/cm^2/sec.

The neutrons probably are produced with several Mev energy[3] and collide with air molecules until they are captured. From the known large slow neutron capture cross section for $N^{14}(n, p)C^{14}$ it is quite clear that the main part of Q must result in the formation of C^{14} atoms in the atmosphere. Korff[8] has given this conclusion previously.

Although most neutrons must form C^{14} there is an additional reaction of lower cross section which seems likely and which appears to offer an explanation of the known larger abundance of the mass three helium isotope in atmospheric helium as compared with gas well helium (10^{-7} part *vs.* 10^{-8} part in well He).[9] The reaction is

$$N^{14}+n=C^{12}+H^3+Q_1 \quad (1)$$

or

$$N^{14}+n=3He^4+H^3+Q_2. \quad (2)$$

This reaction was found[10] with the neutrons from 16-Mev deuterons on beryllium. This neutron source should have resembled somewhat the initial energies of the cosmic-ray neutrons. Since Q_1 is -4.3 Mev and Q_2 is -11.5 Mev, the production of tritium from N^{14} by neutrons requires energetic neutrons. The cross section obtained by Cornog and Libby was 10^{-26} cm^2 with an accuracy of about a factor of five. This source of tritium is of course a source of He^3 in a geologic sense because the 30-year half-life of tritium is so short (tritium emits a negative beta particle to form He^3). If one assumes that the fraction of the cosmic-ray neutrons forming He^3 in this way is about the ratio of the cross sections 10^{-26} cm^2 for the He^3 process to $1.7\cdot10^{-24}$ cm^2 for the C^{14} process, one expects (1/170) Q He^3 atoms per cm^2 per sec. to be produced. Taking the age of the earth's atmosphere to be approximately 1.5×10^9 years this predicts 1.3×10^{-11} Q cc of He^3 per cc of air, whereas the value reported by Alvarez and Cornog is[9,11a,b] about $10^{-7}\times5.239\times10^{-6}$ or 0.052×10^{-11}. Considering the possibilities of loss by escape from the atmosphere, the likelihood of higher concentrations above 25 kilometers[11a,b], the uncertainty of fivefold in the cross section for the He^3 reaction and our ignorance of the neutron spectrum and dependence of the cross section on energy, the agreement seems to be satisfactory.

C. RADIOCARBON IN NATURE

As stated above, it seems probable that nearly all the neutrons eventually form C^{14} and for purposes of calculation we shall neglect the He^3 and other paths entirely and equate the rate of production of C^{14} to Q. Since the age of the earth is much greater than the life of C^{14} a radioactive equilibrium must exist in which the rate of disintegration of C^{14} is equal to the rate of production, Q. In order to calculate the specific activity of atmospheric carbon due to the C^{14} content produced in this way it is necessary to estimate the amount of carbonaceous matter in the atmosphere and on the earth's surface which will be in exchange equilibrium with the atmospheric carbon. This number we shall call B (units: moles of carbon/cm^2). The specific activity then will be Q/B (disintegrations/sec./mole of C).

The estimation of B is difficult. In order to do so we shall assume that the long half-life of C^{14} ($\gg10^3$ yr)[12a,b,c] will insure that all living matter, dissolved matter in the oceans, and a small amount of solid carbonate rocks will be in equilibrium. Taking the biosphere[13] to contain between 10^{13} and 10^{14} tons of carbon, the atmosphere,[13] 6×10^{11} tons; the ocean carbonate,[14] 3×10^{13} tons; and adding 10^{13} tons for rock carbonate in exchange equilibrium, B calculates to be 1.3 moles/cm^2. The possible error in B certainly is at least of the order of a factor of ten, so we shall expect that the C^{14} specific activity of living matter may lie between $\frac{1}{4}Q$ and $2.5Q$, or be about $\frac{1}{5}$ to 2 disintegrations per sec. per mole of carbon.

This is a low figure corresponding to about 10^{-12} curie per gram. However, such radiation levels are detectable in the case of radium and it seems just possible that it can be accomplished with the techniques used in the study of the natural radioactivities of the ordinary elements. An attempt is intended in these laboratories.

It will be particularly desirable to examine C^{13} concentrates for C^{14} if they are prepared from atmosphere or biosphere carbon compounds, and it is hoped that future C^{13} concentration plants will use plant life carbon, when possible, rather than oil, coal, or limestone material in which the abundance of C^{14} should be very low.

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New Units for the Measurement of Radioactivity

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IT has become the custom to express the strength of radioactive sources in terms of curies. This is an erroneous use of this unit since by original definition the curie is

that "amount of radon in equilibrium with one gram of radium"[1] as defined by the Radiology Congress in Brussels in 1910. Therefore, the curie can only be used to represent a rate of disintegration in the radium family. It then represents the disintegration rate of radium or its products in equilibrium. Such a use has been indorsed by the International Radium Commission.

The quantity to be specified in designating the strength of radioactive sources in general is the disintegration rate, determined by the decay constant and the number of atoms of the radioactive isotope in the source. This is simply a number and therefore to establish a suitable unit the only requirement is to select a convenient number of disintegrations per second and give it a name. In selecting this number consideration should be given to insure that it can be readily expressed in sub-multiples, and multiples by the usual prefixes, kilo, milli, micro, etc. A number which fits this requirement is 10^6. Since the curie was named in honor of M. and Mme. Curie, the co-discoverers of radium, it is natural to select the name "rutherford" for the new unit. The appropriate abbreviation is "rd" which conflicts with the abbreviation of no other well-accepted physical unit. The micro-rutherford would become one disintegration per second, a convenient number to remember. Furthermore, the rutherford itself is a small unit of the order of magnitude of many sources used in laboratory measurements. It is sufficiently different in size from the curie that no confusion can arise with the curie in connection with measurements of activities in the radium family. Large sources would require the use of positive powers of ten, which would be preferable to the use of a large unit requiring negative powers of ten.

It should be pointed out that the continued use of the curie for all radio-isotopes not only requires a redefinition of the curie. In addition the value of the curie is uncertain to at least 4 percent and values are in current use well outside this limit. The rutherford provides a definite unit. In addition to eliminating the undesirable use of the curie, the proposed unit also eliminates the basic necessity for measuring radio-isotopes in terms of a standard. Any measuring device which will determine the total number of disintegrations per second will provide directly the strength of the source in rutherfords. A counting arrangement for which the solid angle factor is known is an example. Radioactive standards may be used to determine this factor for a given geometrical arrangement, but other methods are also available.

In the measurement of sources of gamma-rays the roentgen has gained increasing use, largely because this unit is independent of the quality (electron volts) of the gamma-radiation. There is need for a unit in which the intensity of gamma-ray sources can be expressed to eliminate the use of the curie for this purpose. An obvious unit derived from the definition of the roentgen is a roentgen-per-hour at one meter. The roentgen-per-hour at one meter can be abbreviated r.h.m., which again is not readily confused with any other common abbreviation. It has been suggested that this abbreviation can be pronounced "rum." It should be noted that a gamma-ray source equal to one r.h.m. will have a gamma-ray strength 1.18 times that of 1 curie of radium. Therefore, the roentgen-per-hour at one meter has the same order of magnitude as the curie in the measurement of gamma-ray sources.

The National Bureau of Standards, at the suggestion of the Committee on Radioactivity of the National Research Council, recommends the general use of these units.

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Erratum: Experimental Test of Beta-Ray Theory for the Positron Emitters Na^{22}, V^{48}, Mn^{52}, Co^{56}

[Phys. Rev. 69, 313 (1946)]

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THROUGH an oversight, a line was omitted in the manuscript of the above-named paper resulting in a complete reversal of the sense of the last sentence of the abstract. This sentence should read:

> "The type of interaction remains uncertain as does the parity change except that the scalar interaction seems ruled out. The tensor interaction gives consistent results if one assumes parity change in every case except Mn^{52}."

The text of the paper contains the statement in correct form.