Wave Guide Acceleration of Particles

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LINEAR accelerators have been successfully operated to obtain energetic particles, and Hg ions have been accelerated to energies of 1.26 Mev.[1] A major disadvantage in this type of accelerator is the fact that successive electrodes become increasingly longer. This difficulty may be overcome to some extent by using a very high frequency in the accelerator, but a limit is reached when the impressed wave-length becomes comparable to the dimensions of the circuit elements.

The disadvantages mentioned may be overcome by constructing an accelerator from wave guide. The guide could be bent into any suitable geometrical shape, but a relatively simple spiral configuration is shown in Fig. 1. The important point is that the *transverse* field in the guide may be used for the acceleration of particles, and, by proper shaping of the guide, the total ion path may be made quite small. The evacuated system would include the guide and a column of moderate diameter built between the successive spirals of the guide. This type of acceleration should be applicable to either positive ions or to electrons. The problem is relatively simple with electrons, since these particles may be accelerated by very high frequency fields of moderate amplitude; lower frequencies or an initial injection velocity must be used with heavier ions.

Figure 2 shows the maximum potential difference at one megawatt input power which exists between the walls of a wave guide as a function of the width of the guide. This potential difference is inversely proportional to the square-root of the wave-length; values for three different wave-lengths in copper guide at room temperature are shown in Fig. 2. The potential difference becomes arbitrarily large as the width of the guide is diminished to the cut-off point $a_0(=\lambda/2)$, but attenuation also increases rapidly. The value of the attenuation α (if we assume no loss by reflections along the guide) at the various wave-lengths for guides whose width is 1.10 times the cut-off width is given in Table I.

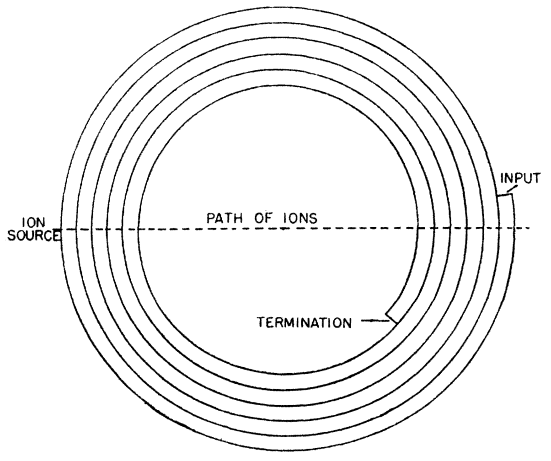

FIG. 1. Schematic diagram of a possible type of wave guide accelerator. If the guide oscillates as a whole, the total length may be as short as will sustain the full input load.

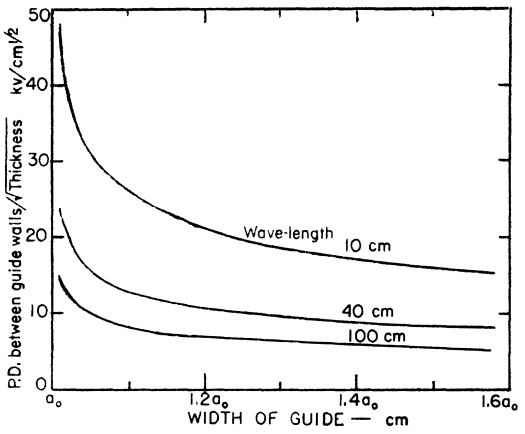

FIG. 2. Potential difference between walls of guide as a function of guide width. The curves were calculated without regard to reflections in the guide. TE_{01} mode; a_0 = critical width of guide; Power = 10^6 watts.

A guide of several meters length could be terminated with a reflector (short circuit), and the whole configuration made to oscillate as a cavity. In such a case, potential differences of perhaps several hundred thousand volts could be realized between the two walls of the guide. Results with single cavity oscillators have already been reported.[2]

TABLE I. Attenuation in wave guide.

λ (cm)	Width of guide (cm)	Thickness of guide (cm)	α (db/meter)
10	5.5	1	0.1075
		2	0.0663
40	22	1	0.0425
		4	0.013
100	55	1	0.0241
		10	0.0030

Proper phasing must be obtained by proper spacing of holes in the guide and by correct separation of the successive turns of the guide. Several units could be operated in tandem to obtain highly energetic particles.

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Atmospheric Helium Three and Radiocarbon from Cosmic Radiation

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A. INTRODUCTION

NUCLEAR physical data indicate that cosmic-ray neutrons produce C^{14} and H^3 from atmospheric nitrogen, the radiocarbon being the principal product. The purpose of this letter is to call attention on this basis

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