Showers of Penetrating Particles at Altitude of 22,000 Feet

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SHOWERS of penetrating particles were observed at an altitude between 21,000 and 23,000 feet in three airplane flights (near São Paulo) with an arrangement XV already described and used by us.[1] The observed frequency of the fourfold coincidences at three different altitudes is given in the following Table I.

Table I. Number of fourfold coincidences in arrangement XV.

	Altitude in meters	Barom. pressure in mm Hg	Number of coincid.	Time in min.	Frequency per 1000 min.
S. Paulo	750	700	135	66 540	2.0± 0.3
C. de Jordão	1750	615	155	21 830	7.1± 0.5
Airplane	7000	340	36	226	160 ±27

These preliminary results show that the intensity of particles generating the showers of penetrating rays decreases very rapidly with the depth in the atmosphere (probably following an exponential law). This variation with depth can be compared with the variation of the abundance of neutrons and protons observed with counters and cloud chambers. But in our case only nucleons with energy $>10^9$ ev come into consideration. The relation with the primary particles and the latitude effects of these showers will be the object of the next study.

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[1] O. Sala and G. Wataghin, Phys. Rev. 67, 55 (1945).

On the Abundance of Nuclei in the Universe

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IN a previous attempt[1] to calculate the abundance of the nuclei in the universe the following assumptions were introduced: the nuclei were formed during the cooling of matter under conditions not far from thermal equilibrium. The neutrinos were tentatively included in the general theory in view of the importance of β-ray processes at temperatures of $\sim 10^{10}$ degrees. This means that we assumed a non-vanishing cross section for absorption of neutrinos and a sufficiently extended and dense distribution of matter in equilibrium, which lasted sufficiently long and allowed inverse β-processes to take place. The numerical calculations were made only for a reduced group of nuclei (with atomic number Z varying from 8 to 20) in order to see whether it would be possible to fix by trial the values of the parameters in such a way as to obtain an approximate agreement between the theoretical abundances, and the observed ones (for this group).[2] This procedure can be applied to other groups and tell us about the conditions of their formation.

One of the purposes of this paper is to correct some errors which appeared in the Fig. 1 of the mentioned letter,[1] for which I am entirely responsible. I am grateful to C. M. G. Lattes, who kindly called my attention to this point. The abundances indicated in Fig. 4 were calculated with the following values of the parameters: $D=525$; $B=525.85$; $a=0.15$; the corrected values (theoretical and observed ones) are indicated in Table I. Lattes also pointed out to me that in his opinion the formalism adopted does not take into account the β-ray processes. In our earlier paper of Lattes and myself communicated to the Brazilian Academy of Sciences (September, 1945, published in 1946) Lattes suggested the following values of the parameters: $B=500$; $D=498.513$; $a=-1.155$. The choice can be further improved in a way to minimize the sum of the squares of the errors for the considered group of nuclei.

Table I. Corrected values of $-\log n(A,Z)/n(16,8)$.

A,Z	Calc.	Obs.	A,Z	Calc.	Obs.
16,8	0	0	29,14	2.4	3.1
17,8	2.9	3.4	30,14	1.8	3.2
18,8	3.6	2.7	31,15	2.6	4.1
19,9	4.4	4.7	32,16	2.7	2.8
20,10	2.4	1.5	33,16	3.0	4.9
21,10	3.3	4.0	34,16	2.1	4.2
22,10	3.9	2.5	35,17	2.6	4.4
23,11	3.0	3.2	36,18	3.8	4.4
24,12	1.7	2.0	37,17	3.6	4.9
25,12	2.7	2.9	38,18	3.7	5.1
26,12	2.7	2.9	39,19	3.8	4.1
27,13	3.1	2.9	40,18	5.3	1.9
28,14	1.8	1.9	40,20	4.7	3.1

Another important point, which will be discussed in detail elsewhere, may be mentioned here; the gravitational energy of the expanding matter, calculated in Newtonian approximation, increases at the expense of the particles' energy, and produces a rapid cooling. Taking into account the great density of nuclei in the problem we are considering ($\sim 10^7$ g/cm^3), one can readily see that the total mass involved in the process of expansion cannot be very great, but must be $\lesssim 100$ solar masses, otherwise the thermal energy ($\sim 10^6$ ev per particles) would not be sufficient to produce the expansion. Thus, it seems that stars were formed (as aggregates of protons, neutrons, and electrons) before the nuclei. Obviously, neutrinos could not come to equilibrium within one star. As was indicated elsewhere,[3] we think that one can describe approximately the process of formation of nuclei as going through a series of nearly equilibrium states which took place in succession during the expansion and cooling of matter. The parameters D, B, a suffered adiabatic changes during the expansion. Indeed their values are determined by the temperature, density of energy and of charge, and number of nucleons per unit volume of the expanding matter. As far as one can deduce from the available very poor observational data, these changes indicate that heavy nuclei were formed at temperatures and densities lower than those corresponding to the formation of the light nuclei.

[1] C. Lattes and G. Wataghin, Phys. Rev. 69, 237 (1946).
[2] Recently calculations concerning all nuclei were published by O. Klein, G. Bescow, and L. Treffenberg, Arkiv. f. Mat. Astr. Fysik 33, 1 (1946).
[3] G. Wataghin, Phys. Rev. 66, 149 (1944).

Half-Life of C^{14}*

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FORMER estimates of the half-life of C^{14} have been based on activity measurements and estimated production yields and have ranged in value from 10^3 to 10^5 years.[1] We have used improved counting techniques with a mica-window Geiger counter tube to obtain a specific disintegration rate of some C^{14} rich samples. The half-life was determined from this and the mass spectrometric measurements of the carbon isotopic abundances.

The geometrical efficiency of the counter tube under measurement conditions was determined by using a uranium standard of known activity, with a backscattering correction made to give the absolute electron flux. This agreed with the measured spherical fraction subtended by the cathode with account taken of the electrode edge effects.

The measured activity was corrected for backscattering of the β-particles, self-absorption, and air and counter window absorption. The thickness of the absorbing layers was integrated over the emission solid angle measured to give the effective layer thicknesses using the method described by Reid.[2] The absorption coefficient was determined independently by inserting filters between a C^{14} source and the counter. The measured values and calculations are given in Table I. Sample I was a Na_2CO_3 solution (thickness > range of β-particles) prepared by quantitative absorption in NaOH solution of CO_2 generated from a $BaCO_3$ sample. Sample II was a sample of the Na_2CO_3 solution dried on an iron plate, the sample somewhat diluted with normal Na_2CO_3. Similar analyses on two other counters with varying absorption and geometry conditions checked within indicated experimental error.

TABLE I. Data for determining the disintegration rate of C^{14}.

	Sample I Thick sample	Sample II Thin sample
Equivalent amount of $BaCO_3$	0.3744 mg/g	3.744 mg
Area	1.676 cm^2	0.7 cm^2
Absorption constant	257 cm^2/g	
Counts/minute	848	1585
Geometric efficiency	14.45%	14.45%
Obliquity thickness factor	1.185	1.185
Self-absorption correction	$\times 304 \frac{cm^2}{g}$	$\times 1.031$
Backscattering correction	$\times 0.97$	$\times 0.90$
Window+air thickness	5.54 mg/cm^2	
Window+air absorption corr.	$\times 5.39$	$\times 5.39$
Disintegrations/sec. mg $BaCO_3$	2.48×10^5	2.44×10^5

CO_2 generated from another portion of the $BaCO_3$ was analyzed on a mass spectrometer.** The spectrum showed a mole fraction of $C^{14}O_2$ of 1.71 ± 0.03 percent. From the mean value of 2.46×10^5 disintegrations per second per mg $BaCO_3$, calculation then gives the disintegration constant for C^{14} as 1.47×10^{-4} yr.$^{-1}$, equivalent to a half-life of 4700 years. The precision of the complete measurement is probably from 5 to 10 percent. Thus 1 gram of C^{14} is equivalent to 5.5 curies or 200,000 rutherfords.[3]

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** Consolidated Engineering Corporation instrument.
[1] S. Ruben and M. D. Kamen, Phys. Rev. 59, 349 (1941).
[2] A. F. Reid, "Detection and Measurement of Radioactive Tracers," *Preparation and Measurement of Isotopic Tracers* (Edwards Brothers, Ann Arbor, 1946).
[3] E. U. Condon and L. F. Curtiss, Science 103, 712 (1946).

"Second Sound" in Liquid Helium II*

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ACCORDING to Landau's[1] quantum hydrodynamical theory of liquid helium II (liquid helium below 2.19°K) there should exist two distinct kinds of wave motion in this fluid. These are, first, ordinary sound vibrations and, second, a type of wave motion unique to this liquid which can be excited only by temperature fluctuations. This latter motion, which has been designated as "second sound" by Landau, has been found experimentally by Peshkov.[2,3] Although the techniques used by Peshkov in the two papers cited differ somewhat in detail, they both make use of an a.c. heater as a source and a phosphor bronze resistance thermometer as a detector. By measuring wave-lengths in either running or standing waves at a known frequency, he is able to determine the velocity of this thermal wave motion in the liquid. Peshkov finds the velocity weakly temperature dependent and gives a value of 1900 ± 100 cm/sec. at 1.4°K. The velocity of ordinary sonic vibrations in helium II is known[4] to be around 24,000 cm/sec., i.e., an order of magnitude higher.

L. Onsager has suggested to us that "second sound" might be converted into normal sound across a liquid-vapor surface by the following mechanism. As Landau and Peshkov have shown, "second sound" consists of temperature fluctuations in the liquid which are propagated with a velocity of some 2000 cm/sec. At the liquid-vapor interface such temperature fluctuations would cause periodic evaporation which in turn would give rise to normal sound in the vapor. In some unpublished computations based on Landau's theory, Onsager has estimated that the transmission across the liquid surface would be of the order of 70 percent.

Accordingly we have performed the following experiment to check these predictions. A Lucite tube was sealed at one end by a disk upon the inside surface of which was wound a flat resistance heater of fine constantan wire. A small magnetic microphone (we used the receiver of a Sonotone hearing aid for this) was sealed into the opposite end of the