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