# LETTERS TO THE EDITOR

## COSMOLOGY

### Conservation of Protons in a Stable Nickel Nucleus

The conservation laws of Nature (for example, charge, energy and baryon number) are considered to be true, since there is no experimental evidence available which proves otherwise. However, there are some theoretical speculations available which consider violations of these conservation laws. Bondi and Gold[1], in their steady-state theory of the cosmos, consider a net production of protons out of 'emptiness', in order to keep the average mass density in an expanding universe constant. Feinberg and Goldhaber[2] remind us that all conservation laws rest only on experimental evidence, and that it is a useful question to search for the limits in which they hold. In this spirit, Backenstoss *et al.*[3] and Giamati and Reines[4] investigated the conservation of baryon number. Alväger *et al.*[5] recently tested the conservation of neutrons in copper nuclei.

Now, it can also be asked : How accurately is it known that in a perfectly closed system the number of protons is constant with time ? Obviously it is difficult to perform the experiment with free protons, but protons, assembled in a nucleus, are a rather good 'closed system'. So the question now is : How accurately is the number of protons in a nucleus conserved ? If the number of protons in a nucleus were not conserved, but in fact increased by one, the nucleus would become isotopic with the next heaviest element. Such a process would clearly violate quite a number of conservation laws and would have some consequences for any theory of knowledge.

As an experimental test for the existence of this process, the following hypothetical reaction was studied:

$$^{60}\text{Ni} \xrightarrow{\text{picking up a proton out of the 'emptiness'}} {}^{61}\text{Cu} \qquad (1)$$

The isotope copper-61 is radioactive with a half-life of 3·3 h and decays with emission of positrons. Twenty kg of pure $NiSO_4 + 7H_2O$ were dissolved in 1/10 N HCl, and 1 g $CuSO_4 + 10$ g $Hg(NO_3)_2$ were added. Copper and mercury were recovered from the solution by precipitation with hydrogen sulphide and the copper then separated from the mixed sulphides by heating in an airstream. This yielded CuO, which was placed between two sodium iodide scintillation crystals arranged to detect positron annihilation quanta in coincidence. No activity above the background of about two coincidences per hour was detected in two experiments. Assigning a half-life $t_{1/2}$ for reaction (1), one can state the result with 80 per cent confidence, as follows :

$$t_{1/2} \text{ [reaction of type (1)] } > 6 \times 10^{18} \text{ years}$$

Alväger *et al.*[5] give the limit for the destruction of neutrons in a copper nucleus under violation of baryon conservation as $> 10^{21}$ years. They discuss their result in the light of the steady-state theory of Bondi and Gold[1] and assume that the average rate of destruction of neutrons is of the same order of magnitude as the rate of creation of matter ($10^{-15}$ nucleons per $cm^3$ per year). They further assume that the actual rate of destruction of neutrons, which is investigated, depends only on the number of nucleons present. They calculate then a half-life of a nucleus against destruction of one of its neutrons with $10^{12}$ years and conclude that the observed stability of nucleons is much greater than 'predicted' by Bondi and Gold[1].

However, it is possible to interpret the limit for the observed stability of a nucleus against spontaneous creation of a proton in such a way as to show that the observed limit for the stability is much smaller than the instability 'predicted' by the steady-state theory. One can assume that the creation of protons is of the same order of magnitude as the creation of the matter and that this creation is only a function of space and that all protons which are created close to the Ni nucleus ($10^{-12}$ cm) are captured by the nickel nucleus. This would give a half-life of the order of $10^{50}$ years for a reaction of type (1). Therefore, the experimental limit reported in this work is much too low to test the 'creation-of-particle' hypothesis of Bondi and Gold[1]. (However, it is not necessary to assume that in the steady-state theory the creation of matter is only a function of space. Hoyle[6] discussed the possibility that creation might depend on the mass density.)

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### Olbers' Paradox

Olbers[1] in 1826 was the first to show that the radiation density everywhere in an infinite static universe should equal the radiation density at the surface of the stars. Hence, Olbers' paradox is that the sky is dark at night.

Let us ignore the absorption of radiation by nonluminous matter. If $E_s$ is the average radiation density at the surface of the stars then the background radiation density in a uniform static universe at time $t$ is :

$$E = E_s\,(1 - e^{-t/\tau_0}) \qquad (1)$$

where $E = 0$ at $t = 0$. In this equation $\tau_0$ is a 'mean collision time' of a photon between emission and absorption by the stars and is :

$$\tau_0 = 4\,V_0/cS \qquad (2)$$

where $V_0$ is a macroscopic element of volume sufficiently large to contain average conditions and $S$ is the surface area of the stars contained in $V_0$. If $\rho_0 \sim 10^{-30}$ g $cm^{-3}$ is the present mean density of luminous matter and $\rho_s$ and $r_s$ are the density and radius of a typical star, then $\tau_0 = 4\rho_s r_s/3c\rho_0$. For main sequence stars such as the Sun it follows $\tau_0 \sim 10^{23}$ years. Thus Olbers' conclusion that $E = E_s$ rests on the assumption that the stars have radiated continuously at their present rate for a time of $t > \sim 10^{23}$ years.

Bondi[2] has examined the assumptions underlying Olbers' argument. Of these assumptions the most important for my purpose are : (*a*) the average density of stars and their average luminosity do not vary throughout space and time ; (*b*) the known laws of physics apply. There is an obvious contradiction between these assump-