lead to nuclei in this region of A (for lighter nuclei the capture will lead to the formation of Ca) and the following elements are too rare and therefore a sharp decrease can be obtained.

It may be noted that in nuclei with the neutron number larger than twenty, the low-lying p-levels are always observed. When the binding energy is large, such levels disappear at $N=50$. For small binding energies they must not be present in nuclei with $N>40$. Thus in the region $20<N<40$ there always exist states in which S-neutrons can make transitions with the emission of dipole radiation.

The probabilities of such transitions are varying proportionally to E^3.

If the capture cross-section for a thermal neutron is equal to 0·2 barns for $E=6{\cdot}5$ MeV (^{40}Ca) then for $E=2$ MeV the capture cross-section must be of the order of 5×10^{-27} cm^2. At an energy equal to 25 KeV (3×10^8 degrees) this cross-section will be equal to 5×10^{30} cm^2 (according to the $1/v$ law). Really the cross-sections are so small only at the latest stages; at larger binding energies they are in the range $10^{-28}<\sigma<5\times10^{-30}$ cm^2. If the capture cross-section is 10^{-29} cm^2, then at the neutron flux 10^{36} cm^{-2} sec^{-1} (that is at densities 5×10^{21} cm^{-3} and velocities 2×10^8 cm/sec), $(1-e^{-10})=100\%$ of the original substance will be burnt in a second. Almost all the substance will be transformed into nuclear species with atomic weights 10–15 units larger. We see that the transformation of light nuclei into medium weight nuclei is possible at very probable neutron fluxes (when the neutron density is equal only to 10^{-5}–10^{-7} of the density of matter in stars). This is a consequence of the presence of dipole transitions in nuclei with $20<A<40$.

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9. ON THE QUESTION OF LIGHT ELEMENTS FORMATION IN STELLAR ATMOSPHERES

B. A. TVERSKOY

It is well known that De, Li, Be and B cannot exist in stellar interiors in amounts that are more than negligible.

Fowler and Burbidges [1] are of the opinion that D, Li, Be and B might be formed by disintegration of heavier nuclei by fast protons (with energy of the order of 100 MeV) accelerated by variable magnetic fields in stellar atmospheres. It is probable that this process causes the anomalously high concentration of Li, Be and B in cosmic rays.

It is easy to show that in conditions of local thermodynamic equilibrium (i.e. Maxwellian velocity distribution) [2] an acceleration of a small part of nuclei is impossible.

It follows that electromagnetic acceleration requires a preliminary transfer of a part of nuclei across the region of thermal electron velocities. A possible mechanism for such a process is the passage of a shock wave towards more rarefied regions of the stellar atmospheres [3].

If those non-Maxwellian particles get into a region of variable electromagnetic fields, they are able to produce a steady acceleration. Continuously gaining energy, a part of them may cause the disintegration of heavier nuclei (e.g. carbon) with Li, Be and B formation.

It follows that the mechanism proposed in [1] explains the anomalously high contents of Li, Be and B in cosmic rays. However, on the other hand, this anomaly is not connected with the true abundance of these nuclei in the Universe.

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As regards the influence of the reactions quoted upon the chemical composition of the stellar atmospheres, one must take into account the following. It is natural that in stellar atmospheres acceleration takes place in the most rarefied regions, where collision losses are small. If at the stellar surface there exists a regular magnetic field, it should not allow the particles to penetrate deeply into the interior of the star and the accumulation of the reaction products should be localized in a thin layer. Even small quantities of D, Li, Be and B, concentrated in a comparatively small region of space, can produce a relatively high concentration.

The accumulation of the reaction products in stars possessing an external convective zone (e.g. the Sun) proceeds quite differently. The point is that the density increases rapidly with depth and at constant concentration the principal number of nuclei should be concentrated in deeper layers.

Even a comparatively thin convective zone might bring the nuclei to a depth where collision frequency becomes comparable with the Larmor frequency in a field of about 1000 gauss and the magnetic field ceases to influence diffusion.

If we assume that a stellar atmosphere is in radiative equilibrium, the change of density with depth is given by a power law [4]:

$$N = n_0 \left(\frac{x}{x_0}\right)^{\alpha}. \tag{1}$$

For the Sun numerically $N \approx 10^{-6}\, x^3$ (where x is the distance from the surface in centimetres).

According to older estimates, the convective zone on the Sun reaches a depth ~ 1000 km. In this case the propagation of D, Li, Be and B inward is determined principally by diffusion.

With increasing distance from the surface the influence of initial and boundary conditions weakens. At a large distance the diffusion is described by an asymptotic law following from the structure of the diffusion equation. It turns out that in a medium of a density increasing according to a power law ($N = ax^{\alpha}$) the diffusion flux has a sharp front. Its position depends on time according to the relation:

$$\frac{a x_f^{\alpha+2}}{DNf} = (\alpha+2)^2, \tag{2}$$

where D is the diffusion coefficient. The value of ND depends but slightly on the density. For the Sun:

$$(2{\cdot}5 \,.\, 10^7\, DNt)^{\frac{1}{2}}. \tag{3}$$

The temperature dependence of x_f is slight ($X_f \sim T^{\frac{1}{2}}$). Assuming $T = 200{,}000°$, $ND = 10^{22}$ (these conditions hold at a depth of 1000 km) and $t = 10^9$ years, one obtains:

$$X_f = 1{\cdot}5 \,.\, 10^9 \text{ cm}.$$

This distance is much larger than the thickness of the reversing layer, the free-path length of particles of 10 BeV energy and the depth of the convective zone according to older estimates.

We may now evaluate the flux of fast particles needed for producing the observed concentration of Li and Be ($\sim 10^{-10}$). It turns out that it is 10^6 cm^{-2} sec^{-1}, which is 10^5 times higher than the observed flux.

If one assumes (see e.g. [4]) that the convective zone reaches a depth of 200,000 km, then the flux should exceed the observed value by 10^{11} times. These estimates do not take into account deuterium, which is a rather abundant isotope on the Earth. The figures given should probably be increased by several orders of magnitude, if it should turn out that deuterium is sufficiently abundant on the Sun as well.

We come to the conclusion that in stars possessing a 'magnetic skeleton', checking the convection and diffusion, nuclear reactions could in principle lead to a quite significant concentration of D, Li, Be and B in a thin layer. We must, however, point out that the mechanism of particle acceleration in such stars is not quite clear, for variable magnetic fields of the kind observed on the Sun arise in all probability as a result of interaction of external convective zones with the general magnetic field of the star. It is possible that the acceleration occurs as a result of divergence of the directions of magnetic and angular momenta.

In stars similar to the Sun, where the external convective zone destroys the magnetic field near the surface and carries the reaction products into the deeper layers, a too large flux of fast particles would be required (at least 100,000 times more than the existing) for producing the observed concentration of Li and Be.

It follows that some other mechanism for the formation of these elements has to be introduced. If it should turn out that D, Li, Be and B are equally abundant in all cosmic objects, including interstellar matter, one should assume evidently that the theories considering the element formation in terms of general cosmology possess a certain amount of truth.

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10. GENERAL DISCUSSION

I. P. SELINOV: Anomalous abundances of Te and Xe isotopes in meteorites and in the Earth permit us to draw some conclusions concerning the age of uranium and the processes of nucleogenesis. According to the estimate by Hoyle the amount of ^{254}Cf disintegrated during a super-nova outburst is of the order of 10^{29} g or 10^{-4} of the stellar mass. According to the fission-yield curve the isotopes of Te comprise about 1% of the mass of fission products. The abundances of Te 128–131 are anomalously high, due to the fission of heavy nuclei. The element abundances do not permit us to draw any conclusions about the *r*-process. The isotopes of Te and Xe with even mass numbers give evidence in favour of the *r*-process (anomalously high abundances). But the amount of Te in meteorites and in Earth is about 1000 times less than it should be if formed during the outburst. The Sikhote-Alin meteorite shows the same anomaly. We may conclude that the heavy elements of the solar system have been formed not in a single super-nova outburst, but as a result of mixing from the totality of outbursts. According to Hoyle, this gives a definite estimate for the age of uranium.

L. H. ALLER: Studies of the abundances of elements in the first two rows of the periodic table in B stars and in the Sun, as carried out by model atmosphere methods, have shown:

1. The more precise the method of analysis, the less the difference between the Sun and the young stars.

2. Uncertainties in the atmospheric models, *f*-values and damping constants limit the accuracy attainable, so that small differences would not be detected.

J. C. PECKER (comment on Mrs Burbidge's paper): Les données sur les abondances citées par Mrs Burbidge sont issues de calculs d'un type 'classique' (courbes de croissance...) qui supposent l'équilibre thermodynamique local (E.T.L.) réalisé dans les atmosphères stellaires. En réalité, il n'en est rien; et le fait de tenir compte des écarts à l'E.T.L. peut entraîner des modifications sensibles: ainsi, dans le cas du Titane, dans la photosphère solaire, il faudrait multiplier l'abondance 'classique' par un facteur de l'ordre de 8 à 10. Les valeurs citées par Mrs Burbidge doivent donc être considérées comme provisoires.

W. P. BIDELMAN: The existence of the horizontal branch and RR Lyrae stars is an observed fact for population II stars. Presumably these objects have all been through the