NUCLEOSYNTHESIS IN THE TERRESTRIAL AND SOLAR ATMOSPHERES

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ABSTRACT
Variations of δD, δ18C, δ16O and δ18O with time have been measured by a lot of experiments. Many abnormalities of isotope abundances in cosmic rays have been found by balloons and satellites. We hold that these abnormalities are related to nucleosynthesis in the terrestrial and solar atmospheres and are closely related to solar activities.

1 Introduction
In recent years, radiative Δ14C in annual rings of trees with different ages at different places, the contents of δ18O in different ice-layers, the contents of δ16C in organic layers at the bottom of the sea, The ratios of (D/H) and the contents of 3H at different altitudes of the terrestrial atmosphere and the ratios of (D/H) in rain, snow and tree have been determined. Variations of the Earth's environment (Temperatures, the contents of CO2 and the heights of the sea level) for several hundred thousand years can be inferred from these data. This kind of research has provided very important informations for meteorology, archaeology and environmental science.

Recently high altitude balloon experiments have observed that the relative abundances of isotope D and 3H, 14N, 22Ne and 24Mg increase greatly. Each nucleus has energy of several hundred Mev and most of them come from the outside of the terrestrial atmosphere. At the same time, satellites have observed that the contents of 3He, when solar flares burst, increase by ~10^6 times or even exceeds the contents of 4He.

We hold that variations of isotopic contents mentioned above are related to nucleosynthesis in the terrestrial and solar atmospheres.

2 Nucleosynthesis in the Terrestrial Atmosphere
The main reactions are,

(1) The bombardment of cosmic rays with the terrestrial atmosphere and its secondary particles can cause many nuclear reactions and the intensity of cosmic rays is modulated by solar activities.

(2) High energy particles produced by solar flares can cause various nuclear reactions in the terrestrial atmosphere.

(3) Protons, in the inner radiative zone of the Earth, can be accelerated to ~100 Mev. They can interact with nuclei in the terrestrial atmosphere to bring about nucleosynthesis.

(4) All three processes mentioned above can produce secondary neutrons and will make neutrons to have a certain intensity, which will change with the
period of solar activities and the terrestrial magnetic latitudes.

Radiative $^{14}$C and $^3$H are obviously the direct evidence of nucleosynthesis in the terrestrial atmosphere. They can be produced by following reactions:

$^{14}$N(n,p)$^{14}$C, ($Q_m=6259$ Mev, $G_{A=1} = 81.005$ b) \hspace{1cm} (1)

$^{14}$N(n, $^{12}$C)$^{3}$H, ($Q_m=-40151$ Mev), $-5\%$ neutrons with $E>4$ Mev \hspace{1cm} (2)

The reaction rate in the terrestrial atmosphere is:

$r = N_N \sigma = \sigma^N N_N$ \hspace{1cm} (3)

where $N_N$ is the density of nitrogen-cylinder in the terrestrial atmosphere and $N_N$ neutron flux. Near the equator, $N_N^{\text{min}}(1)=0$ 110/cm$^2$/sec for the minimum solar activity years and $N_N^{\text{max}}(1)=0$ 105/cm$^2$/sec for the maximum solar activity years. At regions with high latitude, $N_N^{\text{min}}(2)=1$ 367/cm$^2$/sec for the minimum solar activity years and $N_N^{\text{max}}(2)=6$ 709/cm$^2$/sec for the maximum solar activity years.

The amount of $^{14}$C produced at high latitude region is usually 2--5 times as high as that at middle and low latitude regions. Therefore, the results of (1) can be reasonably explained.

By (1), (2) and (3) the average reaction rate forming $^{14}$C in the terrestrial atmosphere at the sea level can be calculated to be $6/cm^2/\text{sec}$ and the reaction rate for $^3$H at stratosphere $3/cm^2/\text{sec}$ (spallation products included).

The main composition of the terrestrial atmosphere are $N$ and $O$. Their cross sections producing $D$, bombarded by incident protons with energy 40 Mev, are measured to be 25 mb and 38 mb, respectively. The cross section producing $^3$H is about 5 times smaller. The cross sections producing $D$ and $^3$H increase with energy of the incident protons.

$^{12}$C accounts for 1 $\%$ of element C and $^{18}$O 2$\%$ of element O. In the terrestrial atmosphere, reactions producing $^{12}$C and $^{18}$O are as follows:

$^{12}$C(p,γ)$^{13}$N(γ,γ)$^{12}$C, ($Q=1$ 2 Kev \ b) \hspace{1cm} (4)

$^{12}$C(n,γ)$^{13}$C, ($Q=3.4+0.3$ mb, $Q_m=9464$ Mev)

$^{14}$N(n,d)$^{13}$C, ($Q_m=-5$ 3260 Mev)

$^{16}$O(n, d)$^{15}$C, ($Q_m=4$ 2156 Mev)

$^{16}$O(d, d)$^{16}$F(γ, γ)$^{16}$O, $^{16}$O(n, d)$^{16}$O, ($Q_m=8$ 8446 Mev)

$^{16}$N(α, p)$^{16}$O, ($Q_m=-3$ 9796 Mev)

$^{16}$O(t, p)$^{16}$O, ($Q_m=3$ 7807 Mev)

Only several Mev kinetic energy is needed for newly produced $D$ and $^3$H to penetrate the Coulomb barrier and to make nuclear reactions possible. The half-life of $^3$H is $T_1/2=12.25$ y and reaction $^3$H(p,γ)$^4$He is easy to take place. Thus for different times there are different $^3$H. It is easy for $D$ in water vapour and newly produced $D$ to react with protons, $D(p,γ)^4$He. Thus, $D$ will decrease.
greatly and there are different D for different times and at different atmosphere heights. Combined with ions OH, D and ³H fall on to the ground as rain and snow, and can be investigated as an index of precipitation and meteorology.

By the same reason, the contents of ¹³C, ¹⁴C and ¹⁸O in the terrestrial atmosphere, after nuclear interaction, will change. The main reactions are as follows,

\[ ^{13}\text{C}(n,\gamma)^{14}\text{C}, (E_n=9+0 \text{ MeV}, Q_m=8 1765\text{MeV}) \]
\[ ^{13}\text{C}(d,n)^{14}\text{N}, (Q_m=5 3260\text{MeV}) \]
\[ ^{13}\text{B}(p,d)^{13}\text{N}, (Q_m=3 9796\text{MeV}) \]
\[ ^{14}\text{O}(x,\gamma)^{15}\text{O}, (Q_m=9 6679\text{MeV}) \]
\[ ^{14}\text{C}(p,\alpha)^{11}\text{B}, (Q_m=3 7869\text{MeV}) \]

Owing to different times of their production and destruction and different diffusion taking place in the atmospheric circulation, there are different δD, δ¹³C, Δ¹⁴C and δ¹⁸O. By determining them, variations of solar activities and the Earth's environment for hundred thousand years can be inferred.

3. Nuclear Synthesis in the Solar Atmosphere. Thermonuclear reactions in the interior of the Sun carry on in the "reactor" with T=15×10⁶ K. The photospheric surfaces with T<10⁸−6000 K are intense convective layers (photosphere), within which there are many kinds of processes of nuclear synthesis. The main processes are:

1. n + D and ³H leaked out from the "reactor" into the convective layers are no longer nuclear fuels. Passing through the chromosphere and corona, D and ³H are accelerated by magnetic field to enter the terrestrial atmosphere. Passing through convective layers and chromosphere, reactions of n, D and ³H will take place, such as p(n,γ)D, D(n,γ)³H, D(D,p)³H, D(p,γ)³He, (H(p,γ)³He, (H(n,γ)³H), (D(D,p)³H, ³He(p,γ)³He, ³He(D,D)³He, (H(p,γ)³He, (Ne(D,p)³Ne, ³He(p,γ)³He, ³He(D,D)³He, (H(p,γ)³He). These are the reasons why remarkable increases in D and ³H have been observed. It has also been observed that the abundances of ³H exceed that of ¹³C and the relative abundance of ²³Ne increase by 2.75 times.

2. There is a good number of high energy particles jetted out at the bottom of the photosphere during solar flares. Thus they can cause many kinds of nuclear synthesis. IMP-8 recorded on May 7th-12th, 1974 that ³He increases by 10⁶ times and exceeds ⁴He, Ne, Mg and Si increase by 10 times. They are caused by reactions D(D,p)³He, D(p,γ)³He, ³He(p,n)³He and ²⁴Ne(α,γ)²⁶Ne, ²³Na(α,γ)²⁵Ne, ²⁴Neα(α,γ)²⁶Na, ²⁴Mg(α,γ)²⁶Mg. These are α-processes caused by temperature rising at some solar flares. Owing to the fact that ⁴He have been consumed greatly and ³He have reached the low temperature regions, the abundances of ³He exceed that of ⁴He and Ne, Mg and Si increase.
3 Conclusions

Following conclusions can be drawn from this paper:

1. There are many kinds of nucleosynthetic processes in the terrestrial and solar atmospheres. They are different to each other.

2. Variations of $\delta^{15}C$, $\delta^{13}C$, and $\delta^{18}O$ are related to solar activities.

3. The super-abundance of $^{22}Ne$ has the solar origin.

4. Abnormalities of abundances in cosmic rays observed in recent years are caused by nucleosynthesis of non-thermal nuclear reactions.

6 References: