SH 2 2-2

NUCLEOSYNTHESIS IN THE TERRESTRIAL AND SOLAR ATMOSPHERES

Chuanzan Yu Renming Zhou Shijie Zhan
Department of Physics, Yunnan University, Kunming
P R C

ABSTRACT
Variations of δD, $\delta^{13}C$, $\Delta^{14}C$ and $\delta^{18}O$ 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 $\Delta^{14}C$ in annual rings of trees with different ages at different places [1], the contents of $\delta^{18}O$ in different ice-layers [2], the contents of $\delta^{13}C$ in organic layers at the bottom of the sea [3], The ratios of (D/H) and the contents of ^3H at different altitudes of the terrestrial atmosphere [4] and the ratios of (D/H) in rain [5], snow [6] and tree [7] have been determined Variations of the Earth's environment (Temperatures, the contents of CO_2 and the heights of the sea level) for several hundred thousand years can be inferred from there data This kind of research has provided very important imformations for meteorology, archaeology and enviromental science

Recently high altitude balloon experiments have observed that the relative abundances of isotope D and ^3H [8], ^{15}N, ^{22}Ne and ^{26}Mg [9] 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 ~10^4 times or even exceeds the contents of ^4He [10]

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 1--100Mev 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=0 6259Mev, σ_{therm}=1 81+0 05 b) (1)

$^{14}N(n, ^{12}C)^{3}H$, (Q_m=-4 0151Mev), ~5% neutrons with E>4Mev (2)

The reaction rate in the terrestrial atmosphere is

$$r=N_N*\sigma*N_n \quad (3)$$

where N_N is the density of nitrogen-cylinder in the terrestrial atmosphere and N_n neutron flux Near the equator, $N_n^{min}(1)$ = 0 110/cm^2*sec for the minimum solar activity years and $N_n^{max}(1)$=0 105/cm^2*sec for the maximum solar activity years At regions with high latitude, $N_n^{min}(2)$=1 367/cm^2*sec for the minimum solar activity years and $N_n^{max}(2)$=0 709/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*sec and the reaction rate for ^{3}H at stratosphere ~0 3/cm^2*sec (spallation products included)

The main composition of the terrestrial atmosphere are N and O Their cross sections poroducing D, bombarded by incident protons with energy 40Mev, are measured to be 25mb and 38mb, 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

^{13}C accounts for 1 1% of element C and ^{18}O 0 2% of element O In the terrestrial atmosphere, reactions producing ^{13}C and ^{18}O are as follows,

$^{12}C(p,\gamma)^{13}N(\beta^+,\nu)^{13}C$, ($s_0$=1 2Kev*b)

$^{12}C(n,\gamma)^{13}C$, (σ=3 4+0 3mb, Q_m=4 9464Mev) (4)

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

$^{16}O(n,\alpha)^{13}C$, (Q_m=-2 2156Mev)

$^{14}N(\alpha,\gamma)$ or $^{16}O(d,\gamma)$ $^{18}F(\beta^+,\nu)^{18}O$, $^{17}O(n,\gamma)^{18}O$, (Q_m=8 0446Mev)

$^{15}N(\alpha,p)^{18}O$, (Q_m=-3 9796Mev)

$^{16}O(t,p)^{18}O$,(Q_m=3 7069Mev)

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-time of ^{3}H is $\tau_{1/2}$=12 25y and reaction $^{3}H(p,\gamma)^{4}He$ is easy to take place Thus for different times there are different δ^3H It is easy for D in water vapour and newly produced D to react with protons, $D(p,\gamma)^{3}He$ 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 invastigated as an index of precipitation and meteorology

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

$^{13}C(p,\gamma)^{14}N$, (s_o=6 0+0 8Kev*b, Q_m=7 5506Mev)

$^{13}C(n,\gamma)^{14}C$, (σ=0 9+0 2mb, Q_m=8 1765Mev)	$^{14}C(p,n)^{14}N$, (Q_m=-0 6259Mev)
$^{13}C(d,n)^{14}N$, (Q_m= 5 3260Mev)	$^{14}C(d,t)^{13}C$, (Q_m=-1 3109Mev)
$^{18}O(p,\alpha)^{15}N$, (Q_m=3 9796Mev)	$^{14}C(p,\gamma)^{15}N$, (Q_m=10 2075Mev)
$^{18}O(\alpha,\gamma)^{22}Ne$, ($Q_m$=9 6675Mev)	$^{14}C(p,d)^{13}C$, (Q_m=-5 9519Mev)
$^{18}O(p,t)^{16}O$, (Q_m=-3 7069Mev)	$^{14}C(\alpha,\gamma)^{18}O$, ($Q_m$=6 2279Mev)

Owing to different times of their production and destruction and different diffusion taking place in the atmospheric circulation, there are different δD, $\delta^{13}C$, $\Delta^{14}C$ and $\delta^{18}O$ By determining them, variations of solar activities and the Earth's enviroments for hundred thousand years can be inferred

3 Nucleosynthesis in the Solar Atmosphere. Thermonuclear reactions in the interior of the Sun carry on in the "reactor" with T=15*10^6 K The photospheric surfaces with T<10^6--6000 K are intense convective layers (photosphere), within which there are many kinds of processes of nucleosynthesis 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 nd ^3H will take place, such as $p(n,\gamma)D$, $D(n,\gamma)^3H$, $D(D,p)^3H$, $D(p,\gamma)^3He$, $^3H(p,\gamma)^4He$, $^{14}N(n,\gamma)^{15}N$, $^{14}N(D,p)^{15}N$, $^{14}N(p,\gamma)^{15}O(\beta^+,\nu)^{15}N$, $^{20}Ne(D,\gamma)^{22}Na(\beta^+,\nu)^{22}Ne$, $^{20}Ne(^3H,p)^{22}Ne$[8] That is the reason why remarkable increases in D and ^3H have been observed It has also been observed that the abundances of ^{15}N exceeds that of ^{14}N and the relative abundances of ^{22}Ne increase by 2 75 times[9]

(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 nucleosynthesis IMP-8 recorded on May 7th-12th, 1974 that ^3He increases by 10^4 times and exceeds ^4He, Ne, Mg and Si increase by 10 times[10] They are caused by reactions $D(D,p)^3He$, $D(p,\gamma)^3He$, $^3H(p,n)^3He$ and $^{16}O(\alpha,\gamma)^{20}Ne$, $^{14}N(\alpha,\gamma)^{18}O(\alpha,\gamma)^{22}Ne$, $^{20}Ne(\alpha,\gamma)^{24}Mg$, $^{24}Mg(\alpha,\gamma)^{28}Si$, i e 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 exceeds that of ^4He and Ne, Mg and Si increase

(3) There is so called "granulation" with diameter of 1500Km Its magnetic field is about dozens of Gausses, by which protons in convection can be accelerated to knock out neutrons from CNO nucleus Thus neutron rich isotopes increase to some extent

4 Discussions

(1) The counting rate recorded at the middle latitude sea level is 20% slower in the maxmum solar activity years than the minimum solar activity years M Stuiver and P D Quay[11], by determining ^{14}C, have found Maunder, sporer and Wolf minimums of solar activities We hold that the rule of older solar activities might be found by comprehensive studies on δD, $\delta^{13}C$, $\Delta^{14}C$ and $\delta^{18}O$

(2) Variations of δD, $\delta^{13}C$, $\Delta^{14}C$ and $\delta^{18}O$ are related to nucleosynthesis in the terrestrial atmosphere In most cases, the experimental data give "-" values, i e the amounts of destruction are more than that of production In order to find out their relations, experiments on the change of $\delta^{15}N$ and $\delta^{17}O$ contents should be carried on

(3) ^{22}Ne super-abundance experiments also observed large increasion in abundances of neutron rich isotopes, such as ^{15}N, ^{17}O, ^{18}O, ^{21}Ne, ^{25}Mg, ^{26}Mg, ^{29}Si and ^{30}Si They should be regarded as a whole and have same origin of non-thermal nucleosynthesis in the solar atmosphere

(4) The abundance of ^{3}He increased by 10^{4} times is not a result of selective acceleration[10], but a result of large amounts of consumption of ^{4}He and ^{3}He jetted out to low temperature regions Thus ^{3}He exceeds ^{4}He Increasions in ^{3}H and D observed by balloons are results of nucleosynthesis in the solar atmosphere at different conditions

5 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 δD, $\delta^{13}C$, $\Delta^{14}C$ 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

[1] C Y Fan, et al , 18th ICRC, V3(1983)82-85
[2] P I Abell, Nature, 297(1982)321
[3] N J Shackleton, et al , Nature, 306(1983)319-322
[4] W Pollock, et al , J Geophys Rev , V85,C10(1980)5555
[5] J R Lawrence, et al , Nature, 296(1982)638-640
[6] I Friedman & G I Smith, Science, 176(1972)790
[7] J R Lawrence & J W C White, Nature, 311(1984)558
[8] W R Webber & S M Yushak, Ap J , 275(1983)391-404
[9] W R Webber, 17th ICRC, V2(1981)261-264
[10] E Mobius & D Hovestadt, IAU Symp No 94, <<Origin of Cosmic Rays>>(1980)395
[11] M Stuiver & P D Quay, Science, 207(1980)11