POSSIBLE NUCLEAR TRANSMUTATION OF NITROGEN IN ATMOSPHERE OF EARTH

Mikio FUKUHARA, Toshiba Tungaloy: a80010@tungaloy.co.jp

Abstract: An attempt to give a possible answer to a question why nitrogen exists so abundantly in Earth 's atmosphere and how it was formed in Archean era (3.8 to 2.5 billion years ago) is presented. It is ascribed to endothermic nuclear transmutation of carbon and oxygen nuclei confined in carbonate $MgCO_3$ lattice of the mantle with an enhanced rate by attraction effect of catalysis of neutral pions produced by electron emission and nutrinos from sun: $^{12}C + {}^{16}O - 2\pi^0 \rightarrow 2\,{}^{14}N$. The cross section

and the reaction rate are determined: $\sigma = \frac{10^6}{E}\exp\left(\frac{-0.470}{\sqrt{E}}\right)$, $R = 9.254 \times 10^{-6}$ f/s/cc.

Keywords: nuclear transmutation of nitrogen, atmosphere of Earth, carbonate in mantle, neutral pion- catalysis

1. INTRODUCTION

When we examine the composition of the atmosphere of solar planets and their sixty-one satellites, we note that the nitrogen concentration is rather low (~ 6%) on the average with exception of the Earth, Titan and Triton.[1] Earth has extremely high concentration of nitrogen of 78%, in Titan and Triton the concentration would be smaller than 2×10^{-6} % and 5×10^{-6} % of the Earth's one, respectively.[2] Since rocky planets having inner orbitals had formed by accretion of solid planetesimals in the same region of the developing solar system at almost the same time,[3] we cannot imagine that abundance of nitrogen is derived from the planetesimals with abundance of nitrogen as the secondary atmosphere, after primary, captured atmosphere was released.[4] A significant question for the origin of abundance of nitrogen has not been entirely resolved, and has been overlooked without the consensus..

When we investigate carefully the variation of various atmospheric gases on the Earth's history, based on an assumption calculated by many research groups,[5)-9)] we find that the decrease in carbon dioxide composition is accompanied by a gradual accumulation of nitrogen into the atmosphere in Archean era (3.8 to 2.5 billion years ago), before the generation of atmospheric oxygen derived from photosynthetic activity by organic matters from around 2 billion years ago. [10] The disappearance means formation of rocks and mantles containing carbon dioxide due to weathering of igneous rocks. The main parts of carbonaceous rocks are distributed on and near the Earth's surface. Thus, consumption of the carbon dioxide, *i.e.*, formation of carbonates, seems to correlate with formation of nitrogen. Therefore we note a possibility of nuclear transmutation between carbon and oxygen atoms in carbonate crystals to form nitrogen.

In a previous paper, [11] the reason why the Earth's atmosphere has such a high concentration of nitrogen was ascribed to a possible endothermic nuclear transmutation of carbon and oxygen nucleus pairs confined along three $[1\sqrt{3}0]$ directions in a (111) plane of rhombohedral $MgCO_3$ crystals existing in the mantle crust. The nuclear reaction is:

$$^{12}C + {}^{16}O - 2\pi^0 = 2\,{}^{14}N, \qquad (1)$$

based on neutral pion catalyzed fusion, [12]

$$^2D + ^2D + 2\pi^0 = ^4He. \quad (2)$$

Kenny [13] has pointed out that the nucleus is charged by electron capture into neutral pion and then decays to produce heat energy. His electropionic mechanism rests on mass alone and sacrifices both baryon conservation and quark consistent pictures of elementary particles. In case of deuteron with lower mass, we have reported the following formula, [14]

$$e^- + ^2D \rightarrow \pi^o + \nu + \gamma, \quad (3)$$

where ν and γ are neutrino and photon, respectively.

Although main carbonate of mantle is dolomite $CaMgC_2O_6$, we select conveniently magnesite $MgCO_3$ instead of dolomite due to lack of crystal lattice data of dolomite under high pressure over 50 GPa. The excited electron e^* was generated by rapid fracture or sliding of carbonate crystals due to volcanic earthquake, and plenty of neutrinos ν were derived from universe, mainly sun. The neutral pion is provided by emission of two excited electrons derived from the carbonate lattice, [15]

$$e \rightarrow e^*, \gamma. \quad (4)$$

$$\gamma + \gamma = \pi^o \quad (5)$$

Here we consider the nuclear reaction of Eq.(1), using low-energy nuclear interaction based on the electropionic attraction. From Eqs.(5) – (8). we got the following formula

$$^{12}C + ^{16}O + 2e^* + 2\nu \rightarrow 2\,^{14}N + ^4He, \quad (6)$$

with help of the electropionic attraction due to the excited electron capture and neutral pion catalysis. We assumed that the formation of nitrogen and helium had continued for 1.3 billion years in Archean era, until the active volcanism or storm of neutrinos ceases. As far as we know, no previous paper has treated this subject, and the formation rate have not been made clear yet. The possibility needs to be confirmed.

2. REACTION RATE FOR ACTIVATED STATE PRODUCT

Since transmutation of nitrogen is attained by instantly occurring spontaneous fission of activated state product $^{12}C^{16}O$ produced by fusion of carbon and oxygen nuclei, we then consider a reaction rate for the product as the transmutation rate.

In the Born-Oppenheimer approximation, the reaction rate R for the C - O reaction is proportional to the probability $|\Psi(0)|^2$, where Ψ is the wave function of the interacting C - O pair at the origin in the center of mass coordinate system, [16]

$$R = D|\Psi(0)|^2, \quad (7)$$

where D is the nuclear reaction constant (dimensions of cm^3/sec). At very low energies the cross section σ [17] for the reaction can be written as

$$\sigma = \frac{D}{V} C_0^2, \quad (8)$$

where V is the relative velocity of the incident particle and C_0^2 is the s -wave Coulomb penetration factor. When the finite size of the interaction volume is neglected, the Coulomb factor at low energies is

$$C_0^2 \approx 2\pi\eta_0 \exp(-2\pi\eta_0) \quad (9)$$

$$\eta_0 = \frac{e^2}{hV}, \quad (10)$$

where η_0 is the Sommerfeld parameter. Fom Eqs.(8), (9) an (10), we obtain the familiar Gamow formula. [18]

$$\sigma = \frac{S}{E} 2\pi\eta_0 \exp(-2\pi\eta_0) = \frac{S}{E} \exp\left(-\frac{\beta}{\sqrt{E}}\right) \quad (11)$$

$$E = \frac{E_{m_2}}{E_{m_1}+E_{m_2}} \qquad (12)$$

where S is astrophysical S factor and β is the Coulomb barrier tunneling constant, E is a reduced energy of masses, m_1 and m_2 of an incident particle and a target nucleus, respectively. Next we introduce the neutral pions. Pions are responsible for all low-energy nuclear interactions and must be involved in the nuclear interaction.[19] If the neutral pion is provided by emission of two excited electrons, the velocity v of the neutral pion can be assumed as $v = 3\times10^5$ m/s.[12] When two neutral pions collides with carbon and oxygen nuclei, we find that

$$2 \times \tfrac{1}{2} m_{\pi^0} v^2 = \tfrac{1}{2} M' V^2 \qquad (13)$$

$$M' = 14\, m_p + 14\, m_n + 50\, m_{\pi^\pm} + 50\, m_{\pi^0} \qquad (14)$$

where m_p, m_n and $m_{\pi^\pm}$ are masses of proton, neutron and charged pion of the activated state product M', respectively, and V is velocity of M', provided that a mass deviation energy is negligible. In eq.(13), six protons and six neutrons in the carbon ^{12}C nucleus are mediated by eighteen charged pions and eighteen neutral pions, while eight protons and eight neutrons in oxygen ^{16}O nucleus are combined by the attractive mediation of thirty-two charged and thirty-two neutral pions. Thus, we obtain

$$V_{M'} = 2.477 \times 10^4 \text{ m/s.} \qquad (15)$$

To obtain the Coulomb factor C_O^2 in Eq.(8), we must calculate η_O. Using Eq.(15), we get

$$\eta_O = \frac{e^2}{hV_{M'}} = 88.37 \qquad (16)$$

Then we consider the screening effect for the Coulomb repulsion to enhance the fusion probability for carbon-oxygen pairs. As is assumed for compacted matter under high pressure, the total number of oscillating electrons in collective resonance for magnesium is ~ 12. Since the screening by many electrons can be apparently treated as one electron with the total mass of all electrons involved, the effective change of carbon and oxygen is reduced to $e/12$ by the electron charge screening effect. This means

$$\eta = \frac{1}{12}\eta_O \qquad (17)$$

From Eq. (17) we get

$$C_O^2 = 4.627\times10^{-19} \qquad (18)$$

Last we consider D in Eq. (7). Here it should be noted that Jackson [17] has reported that the negative meson should be able to act as a catalyst a very large number of times during it's lifetime and the reaction rate in the mesonic molecule will be of the order of 10^6 times that of the observed rate. For this reason, the meason is quite effective in lowering the Coulomb barrier between two nuclei by virtue of its very small orbit around one of them, as if the mesonic atom acts as a neutron in its penetration up to another nucleus. Hence, by analogy we infer that the rate for C - O reaction can be treated as $D = 2 \times 10^{-8}\cdot cm^3/s$, by catalytic help of neutral pions. Thus we get

$$\sigma = 3.7361 \times 10^{-33} cm^2 = 3.736 \times 10^{-9} \text{ barn} \qquad (19)$$

When we consider a pion exchange force between nucleons, we assume that the S factor is enhanced as a function of the force.[20] We apply the effect by the charged pions to that by the neutral pion. Because the addition of two neutral pions increases the S factor ($=10^6$ keV·barn) by four orders of magnitude over conventional two charged pions, using "multibody fusion resonance" model by model by Takahashi *et al.*[20] Thus Eq.(10) gives

$$E = \frac{10^6}{10^{-9}} \times 4.6271 \times 10^{-19}$$

$= 0.1239$ eV. (20)

This value is plausible one as nuclear fusion with C - O system. Substituting $\sigma = 3.736 \times 10^{-9}$ barn, $S = 10^6$ keV·barn and $E = 12.39 \times 10^{-5}$ keV into Eq.(10) gives Coulomb barrier tunneling constant

$\beta = 0.470$ eV. (21)

Thus we have

$$\sigma = \frac{10^6}{E} \exp\left(\frac{-0.470}{\sqrt{E}}\right). \quad (22)$$

The nuclear reaction rate is given by

$$R = N_{C\text{-}O}\ N_{coh}\ V\sigma, \quad (23)$$

where $N_{C\text{-}O}$ is the atomic density of carbon and oxygen, N_{coh} is a multipliciy factor according to lattice-site conditions. If $N_{C\text{-}O} = 10^{22}$ pair/cm^3, $N_{coh} = 10^{21}$, we get

$R = 9.254 \times 10^{-6}$ f/s/cc (24)

3. CONCLUSION

In a previous paper,[11] the formation of nitrogen existing in the present Earth was interpreted to be the results of endothermic nuclear transmutation due to two body confinement of carbon and oxygen nucleus pairs along three $[1\sqrt{3}0]$ directions in a (111) plane of rhombohedral $MgCO_3$ crystals of upper mantle,

$$^{12}C + {}^{16}O - 2\pi^0 = 2\,{}^{14}N, \quad (1)$$

In this study, we calculated endothermic transmutation rate catalized by neutral pions, provided that the activated state product $^{12}C^{16}O$ immediately undergo fission to two ^{14}N nitrogen atoms, accompanied by liberation of four neutral pions. The cross section and rate for the nuclear reaction are given by

$$\sigma = \frac{10^6}{E} \exp\left(\frac{-0.470}{\sqrt{E}}\right). \quad (22)$$

$R = 9.254 \times 10^{-6}$ f/s/cc (24)

The value of $\sigma = 3.736 \times 10^{-9}$ barn deduced in the present study makes the neutral pion catalyzed fusion plausible.

References:

1) Y.Koide,D.Hirata,H.Yamashita and T.Sato, Database of Planetary Science, Res.Rep.Kanagawa Prefect. Mus.Nat. Hist.,Kanagawa, 1987, 13-29 pp.
2) J.Mitton, The Penguin Dictionary of Astronomy, Penguin Book, London, 1991, Table 6, p.349.
3) J.F.Luhmann,J.B.Pollack and L.Colin, The Pioneer mission to Venus, Sci. Am., April, (1994) 68-75.
4) A.Benlow and A.J.Meadows, The formation of the atmospheres of the terrestrial planets by impact, Astrophys.Space Sci., 46 (1977) 293-300.
5) T.Owen, R.D.Cess and V.Ramanathan, Enhanced CO_2 greenhouse to compensate for reduced solar luminosity on early Earth, Nature, 277, (1979) 640-642.
6) H.Ohmoto, When did the atmosphere enhance oxygen?, Kagaku,14 (1994) 360- 370.
7) J.F.Kasting, Theoretical constraints on oxygen and carbon dioxide concentrations in the Precambrian atmosphere, Precamb.Res.,34, 1987, 205- 229.
8) S.J.Mojzsis,G.Arrhenius,K.D.McKeegan,T.M.Harrison, A.P.Nutman and C.R.L.Friend, Evidence for life on earth before 3,800 million years ago, Nature, 384, (1996) 55-59.
9) M.I.Budyko,A.B.Ronov and A.L.Yanshin, History of the Earth's Atmosphere, Springer-verlag, New York, 1985, p.2, 16, 128.
10) L.Van Valen, The history and stability of atmospheric oxygen, Science, 171 (1971) 439 - 443.
11) M.Fukuhara, Possible Origin of Nitrogen in Earth's Atmosphere, submitting to Earth and Planetary Science Letters.
12) M.Fukuhara, Neutral Pion-Catalysed Fusion in Palladium Lattice, Fus.Sci. and Tech., **43**(2002), 128-133.
13) J.Kenny, Electropionics and Fusion, Fus.Tech., **19**

(1991) 547-551.

14) M.Fukuhara,Possible Dynamic Interaction of Deuterons Between Tetrahedral and Octahedral Interstices of Palladium Lattice at Cryogenic Temperatures,Fus.Tech.,**34**(1998)151-155.

15) R.P.Feymann,The Theory of Fundamental Processes, Benjamin/Cummings Publishing Company, 1961, p.37.

16) C.Van Siclen and S.E.Jones, Piezonuclear Fusion in Isotopic Hydrogen Molecules, J.Phys.,G.12 (1986) 213-221.

17) J.D.Jackson, Catalysis of Nuclear Reactions Between Hydrogen Isotopes by μ^- Mesons, Phys.Rev.,**106** (1957) 330- 339.

18) W.P.Allis, Nuclear Fusion, D.Van Nerstrand Company, Princeton (1960) p.1.

19) D.F.MEASDAY and G.A.MILLER,"Hopes and Realities for the Proton-Pion Reactions," Ann.Rev.Nucl. Part.Phys.,**29**, 121 (1979).

20) N.akahashi,T.Iida,T.Takeuchi and A.Mega, Excess Heat and Nuclear Products by D_2O/Pd Electrolysis and Multi body Fusion, Int. J. Appl. Electromag. Mat.,**3**, (1992) 221-230.

21) A.Takahashi,T.Iida and H.Miyamaru, Multi body Fusion Model to Explain Experimental Results, Fus.Tech.,**27**, (1995) 71-85.