The origin of the primordial noble gas isotopic composition in the Solar System. Minoru Ozima[1] and Akinori Yamada[1], Department of Earth and Planetary Sciences, University of Tokyo, Tokyo 113-0033, Japan. E-mail: ezz03651@nifty.ne.jp

Introduction: The isotopic composition of noble gases is a key reference parameter in discussing the evolution of the solar system. Currently, two widely occurring noble gas components are identified in the early solar system, one is the Solar Wind noble gas (SW-noble gas, hereafter) and another is the Q-noble gas in primitive meteorites. Both noble gases are characterized by their ubiquitous occurrence and high isotopic homogeneity. Since the SW-noble gas is directly ejected from the Sun, it has been assumed to be good proxy for the average noble gas isotopic composition of the Sun, namely the solar noble gas. The systematic enrichment of the heavier isotopes in the Q-noble gas relative to the SW-noble gas is then commonly attributed to its isotopic fractionation from the SW-noble gas. Here, we show that the post D-burning Q-noble gas (see below) is better proxy for the solar noble gas in contrary to a conventional view.

Results: The most distinct difference between the Q- and the SW-noble gas is apparent in a $^3He/^4He$ isotopic ratio; 1.23×10^{-4} in Q-He [1], whereas 4.64×10^{-4} in SW-He [2]. The difference is attributed to the conversion of deuteron (D) to ^3He ($D + p \rightarrow {}^3He$) in the Sun, namely the D-burning [3], due to high temperature during the pre-main sequence stage of the Sun. With the use of recent data on H/He ratio (11.75 ± 0.27) from helio-seismology [4] and D/H ratio ($(23.1 \pm 2.4) \times 10^{-6}$) from spectroscopic observation of the inter-stellar cloud [5], we estimate that the $^3He/^4He$ ratio in the post D-burning He in the Sun is $(3.98 \pm 0.3) \times 10^{-4}$. The latter value is considerably smaller than the recent estimate of the SW-He ratio by the GENESIS mission of $^3He/^4He = (4.64 \pm 0.09) \times 10^{-4}$ [2]. We conclude that this difference is due to isotopic fractionation during the ejection of the Solar Wind from the upper solar atmosphere (accelerating region). In Figure 1, we show schematically the isotopic evolution of $^3He/^4He$ in the early solar nebula.

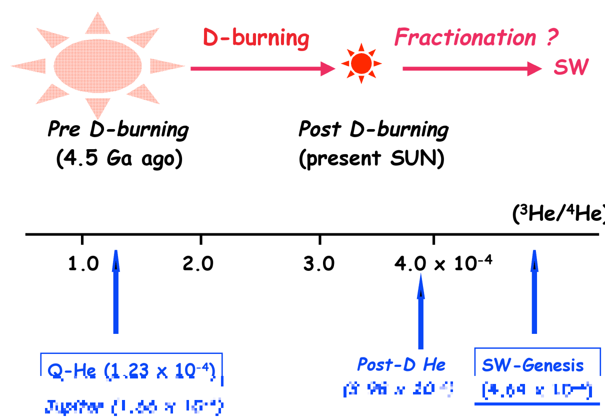

Fig 1. The isotopic evolution of $^3He/^4He$ in the early solar system.

Discussions: We propose that the post D-burning He represents the indigenous solar He. The difference in $^3He/^4He$ between the SW and the post D-burning He amounts to more than 15%, well beyond experimental uncertainty.

Bodemer and Bochsler [6] suggested that insufficient Coulomb drag was responsible to the isotopic fractionation between SW and the solar noble gases. Here, we assume a simple Rayleigh distillation type mass-dependent isotopic fractionation between the SW-He and the post D-burnibg He. This is to assume that the SW-He has been escaping from the upper solar atmosphere with an escape rate inversely proportional to the square root of the mass of an ion, i.e. $(1/m)^{1/2}$. Since the total SW mass ejected from the Sun for 4.5 Ga estimated from the current SW flux is negligible in comparison with the amount of atoms in the outer convective zone of the Sun [e.g.7], we assume the same instantaneous escape rate for 4.5 Ga. The assumption on this Rayleigh type SW escape is then tested with observed noble gas isotopic data below.

In Fig. 2, we plotted the ratio of SW-noble gas [2] to Q-noble gas [1] aginst $(m_i/m_j)^{1/2}$, i,j denoting isotopes. Except for Ne, noble gas data are approximately lie on a slope-one line in accordance with the Rayleigh fractionation. Since Ne isotopic composition in Q is not well defined [1], we discard the Ne datum in Fig. 2.

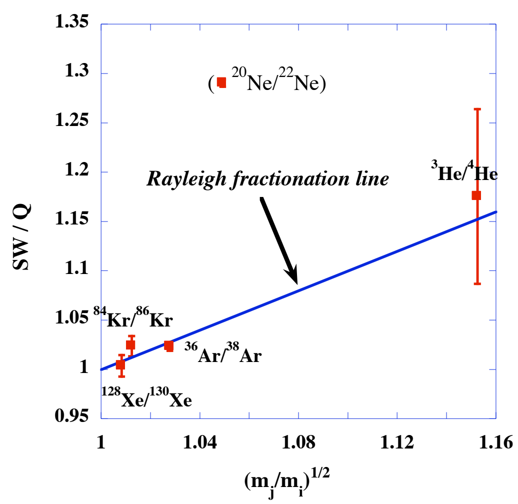

Figure 2. Except for Ne (see text), other noble gas isotopic compositions are consistent with the Rayleigh fractionation of SW-noble gas from Q-noble gas. Error bars are 1σ.

Conclusions

1. SW-noble gas and Q-noble gas are related by mass-dependent, Rayleigh-type isotopic fractionation (Fig.2).
2. Much higher $^{3}He/^{4}He$ in SW than in Q, which is attributed to D + p → ^{3}He (D-burning) in the Sun [3], indicates that Q-He predates SW-He. Therefore, we conclude that the psot D-burning Q-He represents the primordial solar He.
3. With the use of recent observation data on D/H in the pre-solar molecular cloud and H/He in the Sun, we calculate that the post D-burnibg $^{3}He/^{4}He$ is $(3.98 \pm 0.30) \times 10^{-4}$.
4. It remains to see if there is additional isotopic fractionation between SW and the Sun besides the mass-dependent fractionation. Recently CO/O ratio of 0.2 – 0.3 is reported in the lowermost photoshpere [8]. We are examining if the photo-dissociation of CO could give rise to mass-indepenent isotopic fractionation [9].

[1] Busemann H. et al., (2000) *Meteoritics & Planetary Science*, *35*, 949-973,. [2] Heber V. et al., (2009) *Geochimica Cosmochimica Act.a, 73*, 7414-7432. [3] Geiss J. and Reeve H. *Astronomy Astrophysics*, (1972) *18*, 126-132. [4] Basu S. and Antia H.M., (2004) *Astrophysical J.* , *606*:L85-L88, 2004. [5] Linsky J.L. et al., (2006) *Astrophysical J.*, *647*:1106-1124, 2006. [6] Bodemer R. and Bochsler P., (2000) JGR *105*, 47-60. [7] Meyer-Viernet N. (2007) Basics of the Solar Wind. Cambridge Univ. Press, Cambridge. [8] Asplund et al., (2009) *Ann. Rev. Ast. Astrophys. 47*, 481-522. [9] Yamada et al. (2011) *LPSC* (this volume).