LATE IRRADIATION SCENARIO FOR PRODUCTION OF SHORT LIVED NUCLIDES. K. K. Marhas, Planeatry Science Division, Physical Research Laboratory, Ahmedabad, India 380009. kkmarhas@prl.res.in.

The presence of now-extinct short-lived nuclides particularly those with half-life less than ~5 Myrs provide a stringent constraint on plausible source(s) of short-lived nuclides as they necessitate their production and incorporation in a vey short time before or during the birth of the Solar System.

Confirmed presence of now-extinct short lived radionuclide ^{36}Cl ($t_{1/2}$ = 0.3 Myr) in secondary phases of refractory objects have been reported with an initial value ^{36}Cl/^{35}Cl of around 5 x 10^{-6} [1-3]. Very recently, a high initial value (^{36}Cl/^{35}Cl ~ 2x 10^{-5}) has been inferred from a wadalite sample from Allende CAI [4]. Decoupled presence of ^{36}Cl and ^{26}Al in this CAI is a definite indicator of a different source for these two short-lived nuclides. Relative time difference between the formation of two phases incorporating ^{26}Al and ^{36}Cl estimated from the initial value of ^{26}Al/^{27}Al and ^{36}Cl/^{35}Cl points towards the late irradiation scenario[4].

Various irradiation models have been discussed for the production of short-lived nuclides present in the early Solar System. Differences in these models are mainly related to : (a) astrophysical setting for irradiation (distances of the target material from the Sun), (b) physical nature of the target material (gas and dust), (c) composition of the interacting gas and dust, and (d) source of the cosmic ray. The major difference in the models discussed is the location/ region where the production of SLNs is assumed to take place, while Gounelle et al., and Leya et al. [5,6] assume an astronomical setting of X point region of the X wind model located at ~0.06 AU, the model of Goswami et al. [7] consider irradiation at 2-3 AU distance (asteroidal distance) away from the Sun.

Due to a high initial ^{36}Cl/^{35}Cl value (~ 2×10^{-5}) obtained from wadalite in Allende CAI (Calcium, Aluminum-rich inclusion), [4] infered formation of ^{36}Cl to have occurred adjacent to the region in which the CVchondrite parent asteroid accreted and proposed that ^{36}Cl was largely produced by late-stage solar energetic particle (SEP) irradiation. It also indicates SEP irradiation must have occurred >2 Myrs after the formation of the first Solar System solids.

Using the model calculation used by [7], production of ^{26}Al, ^{36}Cl, ^{41}Ca, ^{10}Be, and ^{53}Mn in the early Solar System, due to SEP interaction with nebular material of Solar (CI) composition at asteroidal distances has been recalculated with the constraint on ^{26}Al/^{27}Al value of ~1.6 x 10^{-6} (as observed in the wadalite sample). The SEP flux is adjusted to match the observed initial ^{36}Cl/^{35}Cl ratio in wadalite (~2×10^{-5}), for all the irradiation durations. Fig.1 indicates the irradiation product relative to ^{36}Cl and initial Solar System for spectral exponent (γ) = 2 and 4 with the SEP power law [$dN/dE = kE^{-\gamma}$].

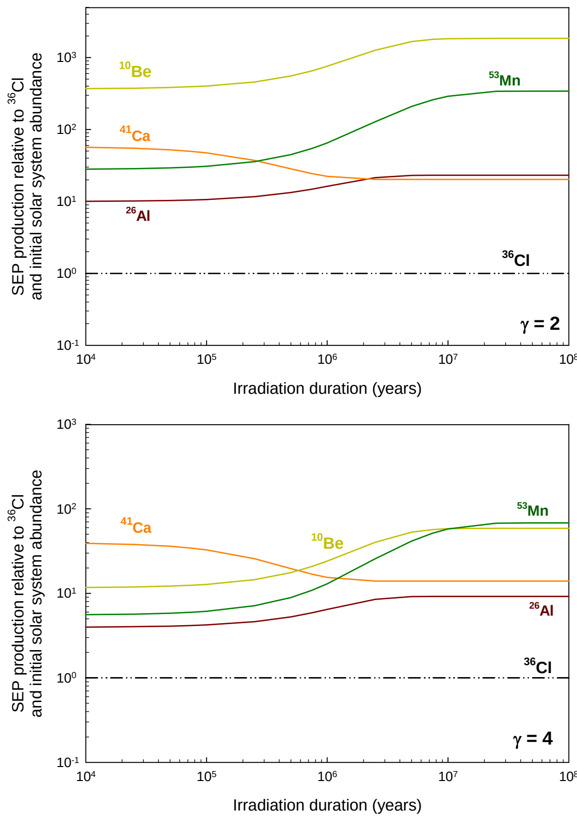

Fig.1. Ratio of calculated to measured Solar System initial ratios of ^{26}Al, ^{36}Cl, ^{10}Be, ^{41}Ca, ^{53}Mn, relative to their reference isotopes, by SEP interactions plotted as a function of irradiation duration with the constraint on ^{26}Al/^{27}Al value of ~1.6 x 10^{-6}. The irradiated objects were assumed to be of Solar (CI) composition following a power-law distribution in size ($dn/dr \propto r^{-4}$) with the spectral exponent of the SEP, γ =2 and 4. The SEP fluence was adjusted to produce an initial ^{36}Cl/^{35}Cl ratio of $2x10^{-5}$ for all irradiation duration.

Late irradiation (>1 Myr) to produce ^{36}Cl with different spectral parameter (flatter or steeper spectra of SEP, γ = 2 or 4) leads to an order of magnitude (or even more in case of γ = 2) higher production of all other short-lived nuclides compared to their observed intial values inferred from the meteorite data. Further calculation with the chlorine-rich secondary precursor phases is under consideration.

References: [1] Lin et al. (2005) PNAS 102: 1306. [2] Hsu et al. (2006) APJ 640: 525. [3] Ushikubo et al. MAPS, 42, 1267. [4] Jacobsen et al. (2011) APJ 731: L28. [5] leya et al. (2003) APJ 594: 605. [6] Gounelle et al. (2006) APJ 640: 1163. [7] Goswami et al. (2001) APJ 549: 1159.