^{41}K EXCESS IN EFREMOVKA CAIs; G. Srinivasan and J.N. Goswami, Physical Research Laboratory, Ahmedabad 380 009, India. A.A Ulyanov, M.V. Lomonosov Moscow State University, Moscow 119 899, Russia.

Studies of potassium and calcium isotopic composition in Efremovka CAIs have provided evidence for excess ^{41}K from the decay of short-lived radioisotope ^{41}Ca ($\tau \sim 0.14$Ma) and an initial (^{41}Ca/^{40}Ca) of $(1.3 \pm 0.2) \times 10^{-8}$. Our observation suggest a time interval of <1Ma between the injection of freshly synthesised ^{41}Ca into the solar nebula and the formation of Efremovka CAIs.

Ion microprobe studies of K-Ca isotopic composition of terrestrial and meteoritic phases were carried out at a mass resolution of $\sim$ 5000, sufficient to resolve the hydride interference (^{40}CaH) at mass ^{41}K. However, the (^{40}Ca^{42}Ca)$^{++}$ interference cannot be resolved at this mass resolution. Since the expected ^{41}K signal for high Ca/K (10^5 - 10^7) phases is extremely low $\leq$ 1(c/s), possible contributions from the doubly charged interference, tail of the hydride peak and the dynamic background of the counting system were monitored during isotopic measurements by obtaining count rates at masses 41.5[(^{40}Ca^{42}Ca)$^{++}$], ^{43}Ca-δM (δM = ^{40}CaH - ^{41}K) and 40.7 repectively. Measurements of terrestrial and meteoritic pyroxenes gave a value of $(2.6 \pm 0.06) \times 10^{-5}$ for the ratio [(^{40}Ca^{43}Ca)$^{++}$/^{43}Ca^{+}] . The dynamic background (at mass 40.7) is typically $\leq$0.01(c/s). We have analysed several terrestrial minerals (microcline, pyroxene, perovskite and anorthositic glass) with extreme Ca/K values ranging from $< 10^{-3}$ to 3×10^6 and all of them yielded normal potassium isotopic composition (Fig. 1). An ion yield factor of 3.2 favouring K over Ca was also determined from these analyses. The meteoritic phases (pyroxenes and perovskite) analysed in this work are from two Efremovka CAIs: E65 (type B1) and E50 (multizoned hibonite rich inclusion). Both the CAIs have ^{26}Mg excess with initial (^{26}Al/^{27}Al) close to 5×10^{-5} [1,2]. The pyroxenes, particularly those with Ca/K $\geq 5 \times 10^5$, have clearly resolvable excess ^{41}K which correlate well with their ^{40}Ca content. A best fit through the data yields a value of $(1.35 \pm 0.2) \times 10^{-8}$ for initial (^{41}Ca/^{40}Ca) and the initial (^{41}K/^{39}K) is close to the solar system value of 0.072.(Fig 1).

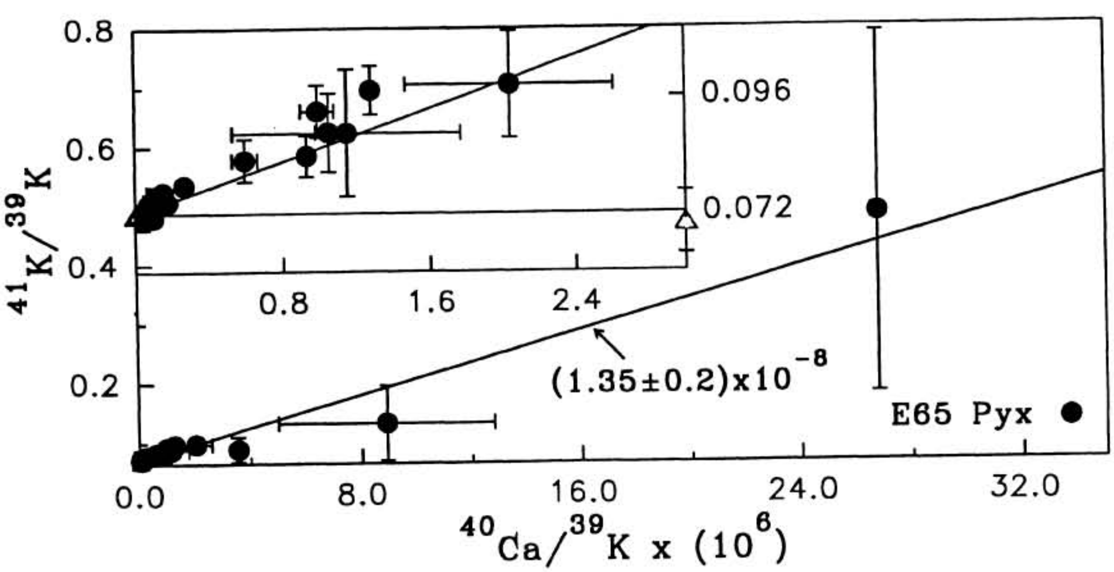

Fig 1. K-Ca isotopic systematics in pyroxene from Efremovka CAI E65. All error bars are $2\sigma_m$. The data points for the terrestrial samples are shown by open symbols.

The observed ^{41}K excess in Efremovka CAIs can result from several possibilities: (i) production by secondary neutrons during the cosmic ray exposure of Efremovka via the [^{40}Ca(n,γ) $\rightarrow$ ^{41}Ca] reaction (ii) 'fossil' ^{41}K locked in refractory interstellar dust that are part of the initial components in the solar nebula from which CAIs are formed (iii) presence of ^{41}Ca in early solar system that was incorporated live into the CAIs during their formation and its in-situ decay. The first and the third alternative can explain the observed correlation between excess ^{41}K and (^{40}Ca/^{39}K) while it is difficult to explain this in the ' fossil' scenario.

We can rule out secondary neutron induced production of the excess ^{41}K, as the required neutron fluence ($\sim 3 \times 10^{16}$ cm^{-2}) is much higher than that expected for the Efremovka meteorite. Although the neutron fluence experienced by Efremovka has not been measured directly, one can make a fairly good estimate by considering the neutron fluence of $\leq 10^{15}$cm^{-2} experienced by the Allende meteorite belonging to the same CV3 group [3]. The recovered mass of Allende (> 2 tons) is much larger than that of Efremovka ($\sim$ 21Kg) and one does not expect the preatmospheric size of Efremovka to exceed that of Allende. Since the cosmic ray exposue age of Efremovka is only twice that of Allende the neutron fluence experienced by it cannot be more than twice the value determined for Allende. This falls short by more than an order of magnitude from the required thermal neutron fluence to explain the observed ^{41}K excess.

The possible fossil record of extinct nuclide decay products and particularly the presence of excess ^{41}K in meteoritic CAIs was first proposed by Clayton [4]. The 'fossil' scenario assumes mixing of stardust having excess ^{41}K with normal solar system matter during the formation of CAIs. One can estimate the magnitude of this excess by assuming interelement fractionation during the formation of stardust and the mixing ratio of stardust and normal solar system matter during the formation of CAIs. While we cannot completely rule out the possibility of the presence of minor amount of 'fossil' ^{41}K in the samples analysed by us, the excellent correlation between (^{41}K/^{39}K) and (^{40}Ca/^{39}K) is extremely difficult to explain in this scenario.

We therefore consider the ^{41}K excess seen in Efremovka CAIs to be a result of in-situ decay of ^{41}Ca in these objects. An earlier attempt to measure ^{41}K excess in Allende inclusions [5] suggested a somewhat lower value of $(8 \pm 3) \times 10^{-9}$ for the initial (^{41}Ca/^{40}Ca) in these objects. ^{41}Ca is the shortest lived radionuclide whose presence in the early solar system can be considered to be established from our data. Its presence places an important constraint on the time interval between the last injection of freshly synthesised ^{41}Ca into the solar nebula and the formation of CAIs. If we consider appropriate stellar production ratio for (^{41}Ca/^{40}Ca) [6], the Efremovka data suggest a value of 1.5Ma for this interval in the absence of nebular dilution. Assuming a possible dilution factor of 10^4, this time interval turns out to be less than 1Ma.

References: [1] Goswami J.N. et al. GCA 57(1993). [2] Goswami J.N. et al. Meteoritics 26, 339 (1991). [3] Göbel R.et al. GCA 46, 1777 (1982). [4] Clayton D.D. EPSL 36, 181 (1977). [5] Hutcheon I.D. et al. Meteoritics 19, 243 (1984). [6] Woosley S.E. et al. APJ 26, 231 (1973).