Contemporaneous formation of condensed and igneous Ca-Al-rich inclusions in the solar nebula inferred from ^{26}Al–^{26}Mg systematics

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Ca-Al-rich inclusions (CAIs) in meteorites, the oldest objects formed in our Solar System [1], are composed of high-temperature condensate minerals from the solar nebular gas [e.g. 2]. Most of CAIs are thought to have contained detectable amounts of live ^{26}Al, a short-lived radionuclide with a half-life of ~0.7 Myr, at their formation [3]. Recent high-precision ^{26}Al–^{26}Mg mineral isochron studies using secondary ion mass spectrometry (SIMS) offer detailed distributions of initial $^{26}Al/^{27}Al$ values, $(^{26}Al/^{27}Al)_0$, for individual CAIs [e.g. 4, 5]. The data of [4, 5] show that high-temperature nebular condensates exhibit extremely narrow ranges of $(^{26}Al/^{27}Al)_0$ ~ 5.2×10^{-5}, while igneous CAIs range from ~5.2 to ~4.2×10^{-5}, corresponding to a formation age spread of ~0.2 Myr. In this study, we newly obtained ^{26}Al–^{26}Mg mineral isochrons of three high-temperature nebular condensates, one fine-grained, spinel-rich inclusion and two fluffy Type A CAIs, from the reduced CV chondrites Efremovka and Vigarano by *in situ* Al–Mg isotope measurements using a SIMS instrument (CAMECA ims-1280HR) installed at Hokkaido University.
The obtained ^{26}Al–^{26}Mg mineral isochron for the fine-grained, spinel-rich inclusion gives an initial $^{26}Al/^{27}Al$ value, $(^{26}Al/^{27}Al)_0$, of $(5.20 \pm 0.17) \times 10^{-5}$. This is essentially identical to the canonical $(^{26}Al/^{27}Al)_0$ determined by whole-rock ^{26}Al–^{26}Mg isochron studies for CAIs in the CV chondrites [7, 8]. On the other hand, inferred $(^{26}Al/^{27}Al)_0$ for two fluffy Type A CAIs, $(4.64 \pm 0.12) \times 10^{-5}$ and $(4.37 \pm 0.12) \times 10^{-5}$, are significantly lower than the canonical value. The range of $(^{26}Al/^{27}Al)_0$ of the observed nebular condensates, from (5.20 ± 0.17) to $(4.37 \pm 0.12) \times 10^{-5}$, corresponds to a formation age spread of 0.18 ± 0.04 Myr, similar to ~0.2 Myr for the igneous CAIs [4, 5]. These data indicate that the nebular condensates formed contemporaneously with the igneous CAIs during ~0.2 Myr from the canonical age. Our findings demonstrate that both condensation and melting of minerals in a hot nebular gas occurred contemporaneously to form various types of CAIs and continued for at least ~0.2 Myr after the birth of the Solar System.

[1] Connelly et al. (2012) *Science* 338, 651–655. [2] Grossman (1972) *GCA* 86, 597–619. [3] MacPherson et al. (1995) *Meteoritics* 30, 365–386. [4] MacPherson et al. (2012) *EPSL* 331–332, 43–54. [5] MacPherson et al. (2017) *GCA* 201, 65–82. [6] Kawasaki et al. (2018) *GCA* 221, 318–341. [7] Jacobsen et al. (2008) *EPSL* 272, 353–364. [8] Larsen et al. (2011) *ApJL* 735, L37–L43.

