Time scales of presolar grains: nucleosynthesis, formation and cosmic ray exposure inferred from noble gas isotopes

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Primitive meteorites - as well as interplanetary dust particles - contain small (up to ‰) amounts of pre-solar "stardust" grains which formed from the winds of evolved stars or from supernova ejecta, survived the harsh conditions of the interstellar medium, were present in the forming Solar System and finally incorporated into these rocks (e.g., [1, 2]). Laboratory study of such *bona fide* stardust provides a ground truth to which to compare the expectations from astrophysical models. Among presolar grains there are chemically robust minerals (diamond, silicon carbide, refractory oxides) but also silicates. Noble gases have played an essential role in their identification and here I review what they may tell us about timescales.

Especially detailed is our knowledge about the source of silicon carbide grains, primarily because they are rich in trace elements with diagnostic isotopic features (e.g., [3]). Most originate from carbon stars and in the heavy elements show the signature of the s-process (slow neutron capture). Data for s-process krypton, by way of the ^{85}Kr (halflife 10.76 a) and ^{79}Se (few years under stellar conditions) branchings constrain the neutron capture timescale [4, 5]. Cosmogenic neon in SiC, on the other hand, offers the possibility to determine the transport time from stellar source to the early solar system [6], but a reliable correction for recoil loss is required [7, 8] and inferred ages are surprisingly short (< 100 Ma). (Probably) radiogenic ^{22}Ne (halflife 2.6 a) in graphite grains from novae / supernovae bears on the timescale for grain condensation [9]. As for the diamonds, noble gases suggest a relation to supernovae, but the detailed overabundance pattern of light and heavy Xe isotopes is puzzling. Possible explanations for the heavy part include a neutron burst in the He shell of an exploding supernova [10] or a modified r-process [11]. Another model involves a "rapid" separation (timescale of hours) between unstable precursors and stable end products of the r-process and has the virtue that it can also be applied to the p-process and the light Xe isotope observations [12]. It is consistent with observations in Te [13] but less so with newly obtained results on Pt [11]. A speculative interpretation for apparent (model-dependent) ^{3}He overabundances in nanodiamonds involves the trapping of cosmic ray ^{3}He (rather than its production within the grains) for periods on the order of 10^{7} a [14].

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