RECOIL OF SPALLATION XENON: HOPE FOR DATING PRESOLAR SIC. R. Mohapatra[1], S. Merchel[1,4], U. Ott[1], U. Herpers[2] and. R. Michel[3], [1]Max-Planck-Institut für Chemie (Otto-Hahn-Institut), Becherweg 27, D-55128 Mainz, Germany (ott@mpch-mainz.mpg.de), [2]Universität zu Köln, D-50674 Köln, Germany; [3]Universität Hannover, D-30167 Hannover, Germany; [4]present address: Bundesanstalt für Materialforschung und –prüfung, D-12205 Berlin, Germany.

Summary: We have determined the recoil range of spallation ^{126}Xe produced by irradiation with 1200 MeV protons in a Ba glas target to be 0.185 µm. The inferred range in silicon carbide is 0.16 µm, which indicates that loss due to recoil out of µm-sized SiC grains should be moderate only – unlike the case of spallation neon. Determining a model presolar exposure age for presolar SiC grains via their content of spallation xenon seems feasible, therefore.

Introduction: A great deal has been learned over the past decade or so from the study of grains preserved in primitive meteorites [1,2]. This is especially true for nucleosynthesis in the stellar sources of these grains and formation conditions in the outflows of those stars; and it is especially true for the grains of silicon carbide most of which (> 90 %) have their origin in carbon stars. Compared to this, direct information regarding the age of these grains is sorely lacking. It had been hoped that cosmogenic neon produced during exposure of the grains to the cosmic radiation while in interstellar space would provide a means to determine a presolar cosmic ray exposure age [3,4]. However, an experimental determination of recoil losses of spallation Ne from SiC grains in the size range of the presolar ones [5] indicated losses to be much larger than assumed in [3,4]. Adding to a number of other problems connected with the approach, these recoil losses - exceeding 90 % for grains of size < 2 µm - effectively make it impossible to use spallogenic Ne for age dating except for possibly the very largest grains. It was suggested, however, that for spallation Xe produced on the abundant Ba in presolar SiC grains the situation regarding recoil loss might be less critical. Here we report on a determination of the recoil range of spallogenic Xe produced in a Ba glass target by irradiation with 1200 MeV protons.

Experimental: The recoil range of spallogenic Ne determined via direct measurement of the retained spallogenic Ne in the grains [5] was found to be in essential agreement with earlier measurements of recoil ranges using the simpler catcher foil technique. Because of this plus because of the fact that catcher foils existed from previous irradiation experiments aimed at determining cross sections for production of spallogenic Xe the catcher foil technique was employed. Here we report first data obtained on catcher foils from an irradiation experiment using 1200 MeV protons (dose 2.3x10^{15} p cm^{-2}) at LNS/Saclay [6]. In the experimental setup two identical Ba glass targets (Ba content 40% by weight, 8% atomic; density 3.5 g/cm³, thickness 3.25 mm, weight 2.01 g) were sandwiched between two Al catcher foils. Xenon in target BGS1152 had been measured by [7]. Xenon in catcher foil CS1141 is a record of recoil from this target emitted in backward direction.. Because of the identical nature of the two targets, CS1151 which contains recoil nuclei emitted in forward direction from target BGS1153, at the same time is a measure of forward recoil from BG1152. Noble gases from the two catcher foils were analyzed by standard noble gas mass spectrometry.

Results and Discussion: Results for ^{126}Xe in the catcher foils are listed in Table 1, together with the results of [7] for Ba glass target BGS1152.

Table 1. Amounts of spallation ^{126}Xe [10^{-12} cm³ STP] in catcher foils (this work) and in Ba glass (from [7]).

catcher CS1141	target BGS1152	catcher CS1151
0.0783	24723	0.826

The effective recoil range can be calculated from the relative amounts of spallation ^{126}Xe in the target and in the forward/backward catcher foils using the equation given in [8] (see also [9]). The result for the recoil range in our Ba glass is 0.185 µm, which according to the range-energy relations given by the TRIM program of [10] corresponds to an average recoil energy of ~630 keV and a range in SiC of 0.160 µm. Such a range is about three times shorter than estimated by [5] based on the observed recoil range of ^{21}Ne and an approximate ΔA/A proportionality in the lower mass range. It is, however, similar to the ~ 0.11 µm range estimated in [9] based on the assumption of proportional momentum transfer at low and high masses coupled with the range-energy relations of [10].

The major outcome of the experiment is shown graphically in Fig.1, which shows the calculated retention of ^{126}Xe in spherical SiC particles as a function of grain size. The important observation is that in the grain size range analyzed for noble gases by [4] losses are quite moderate, with retention in the range 40 to 90%. We have not included range straggling in the calculations shown in Fig. 1, but as shown in [5], inclusion of straggling noticeably changes the results for low retention (<20%) only. As a consequence and as suggested in [5], recoil loss should not be a critical factor in determining an age for presolar SiC particles via their content of cosmogenic ^{126}Xe.

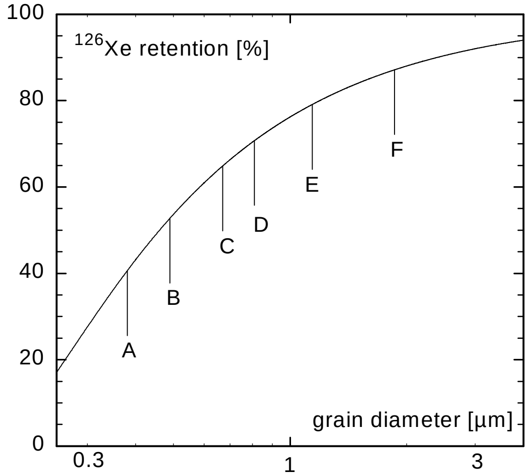

Fig. 1: Retention of spallogenic ^{126}Xe (recoil range 0.16 µm) retained in spherical SiC grains as function of grain size. A, B, C etc. refers to the size of the KJA, KJB, KJC etc. grain size fractions analyzed for their Xe by [4].

Potential other problems with the cosmogenic approach [5] involve the correct production rate for cosmogenic Xe, the possibility of loss of spallogenically produced noble gases (probably less critical in the case of Xe than in the case of Ne) and how to correctly derive the abundance of the cosmogenically produced component. Also here the case of Xe is probably less fraught with problems than that of Ne [5], but still it is not without its share of problems. In the simplest case Xe in SiC is a three-component system comprising a component of s-process origin (Xe-G; [4]), one of approximately normal isotopic composition (Xe-N; [4]) plus the spallogenic component [5].

The composition of Xe-G seems fairly well established [11], especially with the new set of precise neutron capture cross sections for the Xe isotopes reported recently by [12]. The situation seems less clear, however, with the Xe-N component [5]. As far as the spallogenic component is concerned, it is necessary to keep in mind that its composition in the SiC grains may differ to some extent from familiar spallogenic compositions because a) Ba is the dominant, but not the only target element; b) the isotopic composition of Ba in the SiC grains is not solar but rather largely of s-process composition; c) recoil losses are different for the different spallogenic Xe isotopes. This is demonstrated in Fig. 2, where we have plotted the inferred ranges in SiC from our catcher foil analyses for ^{124}Xe, ^{126}Xe, ^{128}Xe and ^{130}Xe vs. the mass difference to the target element Ba. As a consequence, the isotopic composition of the retained spallation component is subject to modification during the recoil process. Still, there seems hope that spallogenic Xe can be used to provide information at least on the general range of the age of presolar SiC grains.

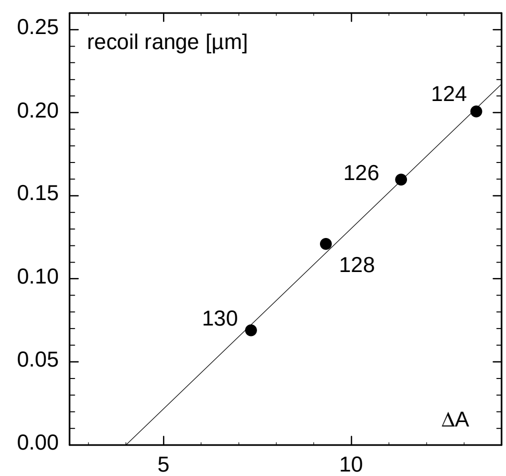

Fig. 2: Recoil range in silicon carbide of various spallogenic Xe isotopes produced on Ba plotted vs. mass difference to target element Ba (atomic weight of Ba: 137.33).

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