PATHWAYS OF IODINE AND XENON INTO TERRESTRIAL PLANETS. S. A. Crowther, M. J. Filtness and J. D. Gilmour, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, M13 9PL, UK (sarah.crowther@manchester.ac.uk).

Introduction: The halogens and noble gases potentially trace the processes by which the "extreme" volatiles on which life depends were incorporated into terrestrial planets. However, our knowledge of the behaviour of these elements on planetesimals is limited and many important questions remain unanswered. Here we focus on iodine and xenon, seeking to understand how they were affected by incorporation into, and processing on, planetesimals.

Analysis of the Genesis samples has confirmed that the xenon composition measured in the young lunar regolith is a true representation of the solar wind [1] and hence reflects the original composition of the average Solar System. In a well mixed Solar System, the xenon compositions of all other reservoirs must have been produced from this composition. The elemental and isotopic compositions of different reservoirs compared to that of the solar wind define the processes by which they were produced and the histories of the environments in which they reside.

The accepted isotopic composition of Q-Xe, the major component trapped in primitive meteorites [2], cannot be directly derived from the composition of solar wind xenon by linear mass fractionation alone [3]. It is best described as mass fractionated solar wind xenon mixed with variable amounts of (presolar) Xe-HL and ^{129}Xe from the decay of ^{129}I [4]. This suggests that the unmodified "trapped xenon" signature was mass fractionated solar xenon; average Solar System xenon was incorporated into primitive meteorites by a process that led to isotopic fractionation.

Iodine and xenon are intrinsically linked: ^{129}I (half life ~16 Ma) decayed in the early Solar System to produce ^{129}Xe. Excesses of ^{129}Xe allow chronological constraints to be imposed on the evolution of reservoirs. The systems can be studied in tandem because artificial neutron irradiation of ^{127}I produces ^{128}Xe, allowing the two elements to be analysed simultaneously. The information which can be obtained from iodine and xenon systematics is wider than the scope of I-Xe dating, which records the time of closure to xenon loss of specific sites.

The pathways by which iodine was incorporated into planetesimals and how it was later redistributed or lost by subsequent processing are poorly constrained. Iodine and xenon systematics suggest that the loss was controlled differently in ordinary and carbonaceous chondrites. H and L chondrites tend to show a trend of lower bulk ^{129}Xe*/I ratios (^{129}Xe* denotes excess ^{129}Xe produced from decay of ^{129}I), corresponding to more

recent model ages, with increasing thermal metamorphism (Fig. 1a), which is understandable in a simple onion shell model of a planetesimal where more metamorphosed samples inevitably took longer to cool [5]. I-Xe data for Acapulcoites and Lodranites demonstrates that rapid cooling after excavation by an impact on the parent body caused this simple relationship to breakdown in some cases [6], and this may account for the apparent spread, but the available data suggest that this was not a universal perturbation. Type 3 ordinary chondrites appear to be an exception to this trend, in retaining low ^{129}Xe*/I ratios corresponding to late model ages or poor retention of the decay product. We speculate that some degree of processing acts to incorporate iodine into sites capable of retaining xenon.

In carbonaceous chondrites aqueous alteration rather than thermal metamorphism is dominantly responsible for secondary processing. They tend to contain high concentrations of trapped xenon compared to most ordinary chondrites [7, 8]. The concentration of iodine appears to decrease with increasing petrologic type. ^{129}Xe*/I appears to correlate with group or oxidation state – CV3$_{red}$, CK4, CO3 generally have higher bulk ^{129}Xe*/I ratios than CV3$_{ox}$, CR2 (Fig. 1b) [5]. There is also a trend for higher ^{129}Xe*/I ratios to be associated with lower iodine concentrations (Fig. 1c). In fact, ^{129}Xe* concentrations tend to be close to 2×10^{10} atoms g^{-1} suggesting the apparent model age variation is a product of variable concentrations of iodine uncorrelated with ^{129}Xe*. Taken together, these observations suggest that most of the iodine in the volatile rich carbonaceous chondrites and the most primitive ordinary chondrites is either situated in unretentive sites such as grain boundaries or in sites that were reset late in Solar System evolution (>50 Ma after CAIs).

Analyses of I-Xe data from nanodiamond separates also suggest late processing of primitive meteorites [9], with one notable exception – nanodiamonds from Allan Hills 77307 (ALH 77307) appear to record early xenon loss about 3 half lives of ^{129}I, ~ 50 Ma, earlier than those from other meteorites.

To further investigate this issue and to gain an insight into the earliest stages of parent body processing from the least processed available samples, we have undertaken analyses of samples of matrix from ALH 77307 (CO3.0) and Acfer 094 (C2-ung).

Experimental: Samples were irradiated prior to analysis, to convert ^{127}I to ^{128}Xe. Aliquots of Shallowater were also included in the irradiations to monitor the

[127]I to [128]Xe conversion. After irradiation xenon isotope ratios and concentrations were measured using the RE-LAX mass spectrometer [10, 11] for all the samples and the aliquots of Shallowater.

Results and Discussion: Two samples of ALH 77303 (0.8 and 3.1 mg) were analysed. These samples were extremely gas rich, with multiple releases for many temperature steps. The [132]Xe concentration (determined from the smaller sample) is ~ 2.35×10^{-9} cm^3 STP g^{-1}. The mean [132]Xe concentrations measured in 3 small (77, 93 and 60 μg) samples of Acfer 094 is $1.31(1) \times 10^{-8}$ cm^3 STP g^{-1}, in good agreement with that measured in other work [8, 12].

Neither ALH 77307 nor Acfer 094 shows a clearly defined I-Xe isochron. An estimate for the upper age limit of ALH 77307 suggests that some of the material closed to xenon loss at ~4568 Ma, ~6 Ma before the I-Xe age of the Shallowater standard [13]. The majority of the xenon releases show later closure, but this upper limit suggests ALH 77307 contains some components which could have been trapped at the beginning of the Solar System and not altered since. It also implies that this meteorite has not undergone any major alteration since closure to xenon loss. An estimate for an upper age limit for Acfer 094 is similar to that of Shallowater (4562.3 Ma [14]) (Fig. 2).

Many of the measured [129]Xe/[132]Xe ratios for Acfer 094 are lower than the accepted Q-Xe ratio, and lie on a mixing line between Q-Xe and fractionated solar wind (Fig. 2). This is consistent with the theory that Q-Xe is derived from fractionated solar wind with the addition of [129]Xe* from [129]I decay. In contrast the majority of releases from ALH 77307 contain excess [129]Xe relative to the Q-Xe ratio, although some did have lower [129]Xe/[132]Xe ratios.

It is inappropriate to compare model ages for these finds with those of the falls discussed above, since terrestrial iodine contamination is a confounding factor (especially for the Antarctic sample). However, it is noticeable that the concentrations of [129]Xe* in these samples are comparable to those of other carbonaceous chondrites, suggesting that aqueous processing has not affected the concentration of retentive sites for iodine in the less primitive meteorites. Whether the variable concentration of uncorrelated iodine reflects primary variation or is a product of (e.g. loss during) aqueous alteration remains unclear.

References: [1] Crowther, S. A. and Gilmour, J. D. (2012) *J. Anal. Atom. Spectrom.,* DOI: 10.1039/C1JA10163C. [2] Busemann, H. et al. (2000) *MAPS, 35,* 949-973. [3] Pepin, R. O. (2000) *Space Sci. Rev., 92,* 371-395. [4] Gilmour, J. D. (2010) *GCA, 74,* 380-393. [5] Gilmour, J. D. (2000) *Space Sci. Rev., 92,* 123-132. [6] Crowther, S. A. et al. (2009) *MAPS, 44,* 1151-1159. [7] Mazor, E. et al. (1970) *GCA, 34,* 781-824. [8] Scherer, P. and Schultz, L. (2000) *MAPS, 35,* 145-153. [9] Gilmour, J. D. et al. (2005) *GCA, 69,* 4133-4148. [10] Gilmour, J. D. et al. (1994) *Rev. Sci. Instru., 65,* 617-625. [11] Crowther, S. A. et al. (2008) *J. Anal. Atom. Spectrom., 23,* 938-947. [12] Crowther, S. A. et al. (2010), 41st *LPSC Abstract #* 1895. [13] Filtness, M. J. (2009) PhD Thesis, University of Manchester. [14] Gilmour, J. D. et al. (2009) *MAPS, 44,* 573-579.
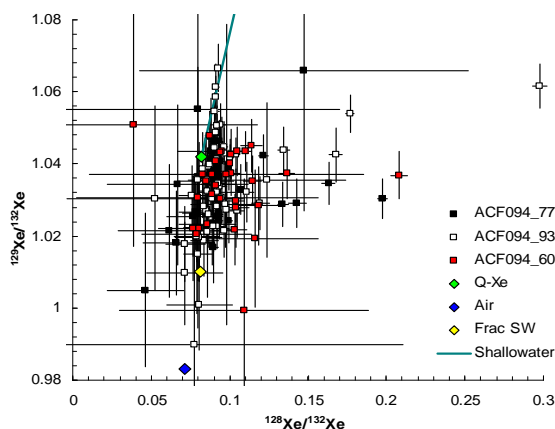

Fig. 2. *Many of the [129]Xe/[132]Xe ratios measured in Acfer 094 are lower than the accepted Q-Xe ratio, consistent with Q-Xe being derived from fractionated solar wind with addition of [129]Xe from [129]I decay.*
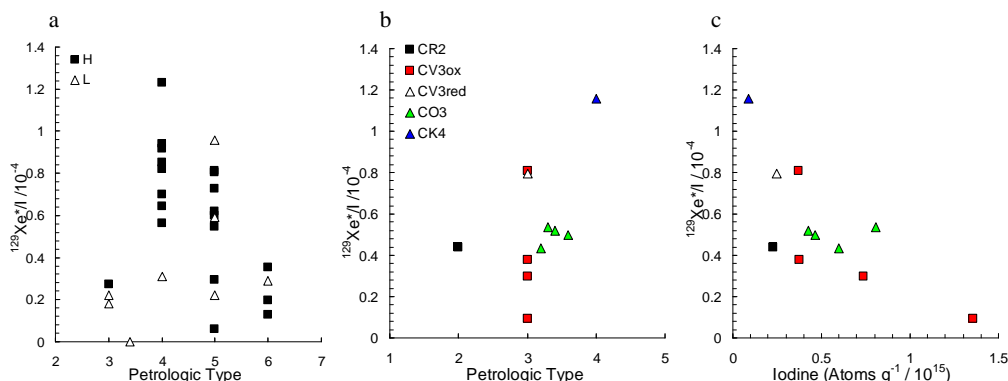

Fig. 1. *Bulk I-Xe data for chondrites. Among the H and L ordinary chondrites, those which have experienced higher metamorphic temperatures have retained less [129]Xe*. Among the carbonaceous chondrites, reduced meteorites tend to have higher bulk [129]Xe*/I ratios that oxidized meteorites. Adapted from Gilmour [5] where data sources are listed.*