SCIENCE PAYOFF FROM NOBLE GAS AND ASSOCIATED HALOGEN ANALYSIS: TOWARDS A SAMPLE WISH LIST. C. J. Ballentine, R. Burgess, S. Edwards and J. D. Gilmour, SEAES, University of Manchester, Manchester, M13 9PL, United Kingdom.

Introduction: Noble gases have long played a central role in the development of our understanding of the evolution of the Earth and interactions among mantle, crust and atmosphere. The key to these developments has been the characterization of the isotopic and elemental compositions of the associated reservoirs. Recent work has concluded that the Earth originated with a noble gas component that was isotopically solar. It is thought that the present-day reservoirs evolved from this composition through outgassing, fractionation associated with loss processes and the admixture of decay products of various unstable isotopes[1].

What we know of the martian system is mostly based on analyses of martian meteorites. The story is somewhat similar. There is evidence of a solar composition for at least part of the martian interior[2]. This signature occurs with varying amounts of fission-derived xenon[3]. The isotopic fractionation of xenon in the martian atmosphere[4] is similar to that of the Earth. In contrast to the Earth, however, the martian atmosphere is more radiogenic than its interior, testifying to significant differences between the early histories of volatiles (especially iodine and xenon) on the two planets.

However, there are inherent limitations to our developing understanding imposed by the use of martian meteorites. In addition to the lack of geological context for our investigations, the samples are exposed to cosmic rays for several million years during transit to the Earth. This leads to the production of spallation isotopes depending on the abundance of appropriate target elements. For xenon, this in fact led to the identification of the host phase of the interior component in Nakhla[5]. However, the high concentrations of target elements for He and Ne production mean that the signatures of these elements in martian reservoirs are very poorly constrained..

In addition to helping us define models of martian evolution, noble gas analyses can make other important contributions. The Ar-Ar technique based on decay of ^{40}K to ^{40}Ar will play a significant role in determining absolute ages and calibrating the cratering timescale provided appropriate samples are selected. The Ar-Ar technique requires neutron irradiation, that also allows cosmic ray exposure ages to be determined based on the production of ^{36}Ar from Ca, while noble gas isotopes produced by neutron capture allow relative abundances of the halogens Cl, Br and I to be derived. Thus, noble gas analysis will allow a detailed understanding of the volatile evolution of Mars to be developed.

Sample Wish List: Constraining planetary evolution depends on the characterization of planetary reservoirs. To this end, a returned atmospheric sample is crucial to allow both detailed comparison with the heavy element composition understood from martian meteorite analyses (hence addressing atmospheric evolution) and the first tight constraints on the isotopic signatures of the light isotopes. An in situ atmospheric measurement is unlikely to have the required precision (e.g. Viking), but would allow the issue of contamination between sample collection and analysis to be addressed.

Understanding of the martian interior is likely to be best addressed through analysis of igneous rocks. Within 3 m of the surface the cosmic ray flux is greater than that at the Earth's surface. Combined with low erosion rates this suggests deep samples will be required to preserve the signatures of parent reservoirs against overprinting by spallation. The solution is to seek either buried or recently exposed samples, or samples from recent lava flows.

Dating techniques applied to sedimentary rocks tend to yield ambiguous results, thus calibration of the cratering timescale will also require suitable samples of igneous rock. However, the halogen composition of sedimentary rocks deposited from water can potentially play an important role in understanding the history of the parent water body.

Technology: The current state-of-the-art in noble gas mass spectrometry is commercially available multi-collector , electron impact instrumentation and experimental, element specific resonance ionization, time-of-flight instruments for xenon and krypton, all of which are available in Manchester. Detection limits of ~1000 atoms are achievable, but for martian samples 10^5 – 10^6 atoms represent useful sample sizes. For xenon, this corresponds to ~1 mm^3 of the present-day martian atmosphere. Based on analyses of martian meteorites, samples of ~1 mg are required for characterization of xenon in the interior component. For Ar-Ar and halogen determinations 1-2 mg samples are indicated.

[1]e.g. Ballentine et al. (2005) Nature 433 33-38. [2]Ott U (1988) GCA 52 1937-1948 [3]Mathew and Marti (2002) EPSL 199, 7-20 [4]e.g. Swindle et al. (1986) GCA 1001-1015 [5]Gilmour et al. (2001) GCA 65 343-354.