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Ultrasensitive xenon isotopic analysis as part of coordinated analyses of returned samples

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Noble gases are key tracers of Solar System evolution. Xenon has enough isotopes for multiple contributing sources to be unambiguously identified. Distinct xenon isotopic signatures have been identified in the sun [1], primitive meteorites [2], and the coma of a comet [3]. ^{129}I, ^{238}U and ^{244}Pu decay on different timescales, producing characteristic xenon isotopic signatures. Artificial neutron irradiation of ^{127}I, ^{130}Ba, ^{130}Te and ^{235}U produce characteristic xenon signatures. Exposure of samples containing barium and light rare earth elements to cosmic rays produce xenon from spallation and secondary neutron capture reactions.

The RELAX (Refrigerator Enhanced Laser Analyse for Xenon) mass spectrometer is an ultrasensitive, time of flight, resonance ionisation mass spectrometer for measuring xenon isotope ratios in extra-terrestrial materials [4]. Ratios of the major isotopes can be determined to 1 % from a single analysis of 10^5 atoms per isotope. Measurements are reproducible; precise isotope ratios can be determined by averaging repeat analyses. RELAX is particular applicable to analysis of materials collected by sample return missions. RELAX can make useful xenon isotopic measurements on small samples, complementing conventional noble gas mass spectrometry. Grain to grain variations can be investigated, and less material is consumed. Samples can be chips ≲3 mg, single grains, or mineral separates.

To fully understand xenon data, samples should be characterised by non-destructive techniques prior to xenon analysis. Mineralogical and petrological information provide context for interpreting xenon data. Determining concentrations of uranium and spallation target elements allow calculations of U-Xe and cosmic ray exposure ages respectively. Mounting of samples for characterisation must not compromise xenon analyses: samples cannot be impregnated with epoxy or crystal bond.

I-Xe dating requires artificial neutron irradiation of samples prior to analysis, with fluences $\sim 10^{19}$ n/cm^2. Enstatite from Shallowater (aubrite) is irradiated and analysed alongside the samples, to monitor the conversion of ^{127}I to ^{128}Xe. It is desirable to also include monitors for conversion of ^{130}Ba, ^{130}Te and ^{235}U to xenon isotopes.

[1] Crowther & Gilmour (2013), *GCA* 123, 17-34.

[2] Busemann *et al*. (2000), *MAPS* 35, 979-973.

[3] Marty *et al*. (2017), *Science* 356, 1069-1072.

[4] Crowther *et al*. (2008), *JAAS* 23, 938-947.