PRODUCTION RATES OF NEON AND XENON ISOTOPES BY ENERGETIC NEUTRONS

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As a first step in a new experimental program to study the behavior of noble gases produced in situ in minerals, we have irradiated a suite of minerals and pure chemicals with 14.5 MeV neutrons at LLNL's Rotating Target Neutron Source (RTNS-II) and determined production rates for noble gases. While neutron effects in meteorites and lunar samples are dominated by low-energy (<1 keV) neutron capture, more energetic cosmic-ray secondary neutrons can provide significant depth-dependent contributions to production of cosmogenic nuclides through endothermic reactions such as (n,2n), (n,np), (n,d) and (n,alpha). Production rates for nuclides produced by cosmic-ray secondary neutrons are therefore useful in interpreting shielding histories from the relative abundances of cosmogenic nuclides.

Samples were vacuum encapsulated in quartz ampoules and irradiated as add-ons to the principle RTNS-II experiments for two to four weeks, during which time they accumulated fluences up to 10^{17} neutrons/cm^2 as determined by activation of iron dosimetry foils. Irradiated samples were stored for at least three months before breaking open the quartz ampoules and weighing portions for analysis. Noble gas isotope dilution analyses were performed by adding an aliquot of our mixed noble gas spike (principally ^{3}He, ^{21}Ne, ^{38}Ar, ^{80}Kr, and ^{124}Xe) or of an air standard during a single 1650 C vacuum extraction. Duplicate samples were analyzed without the spike in two-step extractions: a 400 C heating to reveal any tendency for low-temperature gas loss, and a 1650 C extraction. Only insignificant quantities of noble gas reaction products were released in the 400 C steps, leading us to conclude that gas retention was probably quantitative, although we cannot rule out the possibility of some recoil loss during the irradiations or diffusive loss at ambient temperatures during and after the irradiations.

Neon analyses were performed on samples of sodium and magnesium minerals and reagents. The neon extracted from sodalite, albite, and NaCl samples are isotopically similar, determining the composition of Na-derived neon as ^{20}Ne:^{21}Ne:^{22}Ne = 0.45:0.017:1, not including the ^{22}Ne that will grow in from decay of 2.6-year ^{22}Na from ^{23}Na(n,2n)^{22}Na. The neon extracted from the magnesium minerals enstatite and forsterite are also isotopically similar, with a composition given by ^{20}Ne:^{21}Ne:^{22}Ne = 0.61:1:0.090 attributed to

production from natural magnesium. The neon extracted from Mg metal was isotopically different from the neon extracted from the magnesium minerals, probably due partly to differences in the neutron energy spectrum seen by the different samples and partly to atmospheric neon contamination in the Mg metal. Unlike the other reagent samples, it had not been degassed by vacuum melting before encapsulation. At present, we can only give the measured isotopic composition in the unspiked 1650 C extraction from this sample as limits for the Mg-derived neon: $^{20}Ne/^{21}Ne < 0.75$, $^{22}Ne/^{21}Ne < 0.095$. The atmospheric neon contamination does not compromise the isotope dilution analysis of ^{21}Ne production in Mg-metal, and our value of 136 $\pm$ 7 mb for this production cross section is in fair agreement with previous measurements of 160 $\pm$ 8 mb at 14.1 Mev and 152 $\pm$ 12 mb at 14.7 MeV (1).

Xenon analyses were performed on samples of CsCl and $Ba(NO_3)_2$. The Cs-derived xenon was dominated by ^{132}Xe primarily from $^{133}Cs(n,2n)^{132}Cs$, but ^{130}Xe from $^{133}Cs(n,alpha)^{130}I$ was also measured, with $^{130}Xe/^{132}Xe = 0.0014$. The major isotopes in the Ba-derived xenon were ^{131}Xe from $^{132}Ba(n,2n)^{131}Ba$ and ^{129}Xe from $^{130}Ba(n,2n)^{129}Ba$. Lesser amounts of other xenon isotopes were also produced, with relative abundances given by $^{129}Xe:^{130}Xe:^{131}Xe:^{132}Xe:^{134}Xe$ = 1:0.019:1.084:0.221:0.194.

Absolute production cross sections were calculated from the isotope dilution analyses of the NaCl, Mg, CsCl, and $Ba(NO_3)_2$ samples, assuming purity, stoichiometry, and quantitative noble gas retention and extraction. Relative production cross sections determined from neon isotopic ratios in the mineral samples were also considered in evaluating the neon production cross sections. Results are given in the accompanying table.

Reference: (1) Reedy R. C., Herzog G. F. and Jessberger E. K. (1979) Earth and Planetary Science Letters, 44, p. 341-348.

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Table: Production cross sections for Ne and Xe isotopes by 14.5 MeV neutrons.

Target	Product	Cross Section (mb)
^{23}Na	^{20}Ne	137 ± 7
^{23}Na	^{21}Ne	5.2 ± 0.4
^{23}Na	^{22}Ne	304* ± 15
^{nat}Mg	^{20}Ne	83 ± 5
^{nat}Mg	^{21}Ne	136 ± 7
^{nat}Mg	^{22}Ne	12.2 ± 0.7
^{133}Cs	^{130}Xe	2.4 ± 0.3
^{133}Cs	^{132}Xe	1730 ± 90
^{nat}Ba	^{129}Xe	1.65 ± 0.08
^{nat}Ba	^{130}Xe	0.031 ± 0.002
^{nat}Ba	^{131}Xe	1.79 ± 0.09
^{nat}Ba	^{132}Xe	0.37 ± 0.02
^{nat}Ba	^{134}Xe	0.32 ± 0.02

* Not including ^{22}Ne from ^{22}Na decay