

TERRESTRIAL XENON IN NOBLE GAS RESERVOIRS. P. Boehnke¹ and M. W. Caffee¹, ¹Department of Physics, Purdue University, West Lafayette, IN 47907-1396, USA (pboehnke@purdue.edu).

Introduction: While xenon is only a trace constituent, it nonetheless has great importance in delineating processes in Earth's early history. Xe has nine stable isotopes allowing for many isotopically distinct reservoirs. In a seminal work Staudacher and Allegre [1] proposed that: 1) Xe in the atmosphere is outgassed from the upper mantle; and 2) the fissionogenic Xe is dominated by ²⁴⁴Pu-derived Xe. This interpretation is consistent with calculations done by Pepin and Phinney [2] indicating that the fissionogenic Xe in Earth's atmosphere is largely composed of ²⁴⁴Pu-derived Xe, with some contributions from ²³⁸U. However, detailed decompositions of mantle-derived Xe indicated dominantly a ²³⁸U progenitor [3 and references therein]. Nonetheless, there is considerable evidence that ²⁴⁴Pu was present in the early Earth. Xe from > 1 Ga diamonds found in Botswana, Zaire and from zircons found in Australia provide ample evidence for ²⁴⁴Pu-derived Xe in the early Earth [4,5].

Caffee et al [6] observed that the best fit to Xe isolated from CO₂ well gases was a mixture of atmospheric Xe and a meteoritic component, tentatively identified as solar-Xe. Assuming solar-Xe and atmospheric-Xe as the underlying components Caffee et al [6] determined that ~ 86% of the fissionogenic Xe in the CO₂ well gases is derived from ²³⁸U decay, the remainder of the fissionogenic Xe is from ²⁴⁴Pu. Pu-derived Xe is also evident in other solar system materials. Hudson et al [7] determined a ²⁴⁴Pu/²³⁸U ratio in the early solar system of 0.0068±10. Pu-derived Xe is also evident on lunar grains [8 and references therein]. It is surprising given these observations that there is not

Table 1. Xe compositions

<i>Component</i>	<i>Coefficient</i>
Air-Xe	.8925
²⁴⁴ Pu-Xe	.175
¹²⁹ I-Xe	.0804
Q-Xe	.0725
SW-Xe	.035
²³⁸ U-Xe	.025
P3-Xe	.0075

more ²⁴⁴Pu-derived in Earth's mantle.

In the years since the work of Pepin and Phinney, [2] and others, many isotopically distinct reservoirs of Xe have been identified in meteorites. In this work we revisit the earlier decomposition results of Caffee et al [6], using the Xe components shown in Table 1. Our approach is not only to find the best fit for the mantle-

derived-Xe using these meteoritic Xe reservoirs but also to investigate the sensitivity of the ²⁴⁴Pu/²³⁸U ratios to variations in the mixture of these components.

Methods: Computer-based algorithms were used to decompose terrestrial Xe compositions taken from the literature Table 2 shows the individual Xe components into which terrestrial reservoirs (Table 3) were decomposed. The fraction of each component (represented numerically as a vector) is represented as a coefficient. All the components are summed to obtain a synthesized mixture. For each mixture the square residuals are calculated. The best fit is determined from these residuals. The best fit composition was then used to calculate ²³⁸U to ²⁴⁴Pu ratios as well as a Xe closure age.

Results and Discussion: The decomposition found an underlying component composed primarily of atmospheric Xe, Q-Xe, and solar-Xe. For non-radiogenic Xe this composition is dominated by atmosphere-Xe, Q-Xe and solar-Xe with some P3-Xe. Figure 1 shows the decomposition for a non-radiogenic Xe isotope, ¹³⁰Xe. This decomposition yields a similar amount of non-atmospheric Xe as was determined by Caffee et al [6]. For the light Xe isotopes the primitive components are indistinguishable so a decomposition based solely on ¹²⁴⁻¹³⁰Xe cannot uniquely resolve the nature of the primitive component. We nonetheless have identified the presence of Q-Xe on the basis of the heavy Xe isotopes.

Figure 1. The constituents as shown for ¹³⁰Xe in MORB

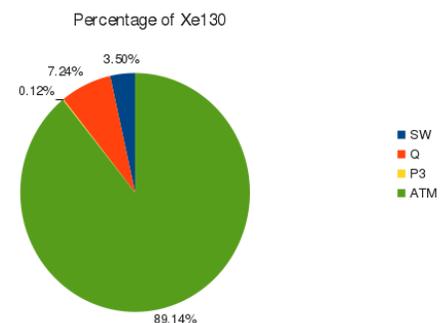
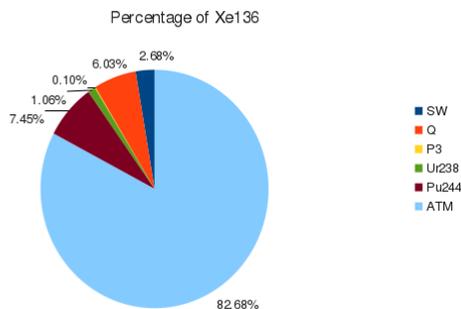


Figure 2 shows the decomposition of ¹³⁶Xe. The heavy Xe isotopes not only reflect the additions of fissionogenic Xe, both ²⁴⁴Pu- and ²³⁸U-derived, but the isotopic abundance of the primitive components differ from each other as well. Our salient observation using a combination of primitive meteoritic components is that ²⁴⁴Pu-derived Xe is now the dominant source of fissionogenic Xe in MORB. Previous decompositions of

MORB indicated that ~40% of the fissiogenic Xe was attributable to ^{244}Pu , the balance being derived from ^{238}U [6,9]. Using our decomposition we identify the fraction of fissiogenic Xe from ^{244}Pu as .87, about twice previous estimates. Using our results we obtain a MORB $^{244}\text{Pu}/^{238}\text{U}$ ratio of 0.0028 using the fission yields given in [10 and references therein] or 0,0044 using the fission yields in [11 and references therein].

Figure 2. The make up of ^{136}Xe in MORB



Like previous decompositions we identify the presence of ^{129}I -derived ^{129}Xe . Using the method of Wetherill [12] we can calculate a $^{129}\text{I}/^{244}\text{Pu}$ closure age of ~ 120 Myr. This calculation uses parameters from Pepin and Porcelli [3] and follows the calculation described by Swindle et al [8].

Conclusion: Using numerical techniques we have identified primitive meteoritic Xe constituents in terrestrial Xe reservoirs. Our calculations indicate that the dominant fissiogenic Xe contributor to MORB Xe is ^{244}Pu . We also identify the underlying primitive constituents as a combination of Q-Xe, solar-Xe, with minor contributions from other Xe components.

References:

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Table 2. Xe components

Component	124	126	128	129	130	131	132	134	136
Air [3]	2.337	2.18	47.15	649.6	100	521.3	660.7	256.3	217.6
SW2 [3]	2.928	2.534	50.83	628.6	100	499.6	604.7	220.7	179.7
Q [3]	2.81	2.506	50.77	643.6	100	505.6	617.7	233.5	195.4
^{238}U [3]	0	0	0	0	0	8.47	57.17	82.47	100
^{244}Pu [3]	0	0	0	0	0	24.8	89.3	93	100
^{129}I	0	0	0	100	0	0	0	0	0
P3 [13]	0.451	0.404	8.06	104.2	15.91	0.8232	100	37.7	31

Table 3. Terrestrial Xe compositions

Reservoir	124	126	128	129	130	131	132	134	136
MORB [3]	2.39	2.224	47.52	706	100	524.1	672	272.2	235.2
Caroline CO ₂ [6]	.3557	.3307	7.090	105.92	14.94	77.945	100	40.564	35.278