

ISOTOPIIC ANOMALIES IN THE ORGUEIL METEORITE: NEON-E, s-PROCESS Xe, and CCFXe
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Continuing our systematic study of noble-gas host phases in primitive meteorites (1,2,3), we have examined 4 chemically separated samples from the Orgueil CI chondrite (Table 1). The parent sample A10.1 was an HF, HCl-insoluble residue of assorted silicate fractions from which magnetite had been removed (4), A10.2 was a partially (~50%) successful attempt to remove the organic polymer without affecting other phases, whereas A10.3 was an "etched" sample, treated with strong oxidizing agents to remove Q and the polymer (3). All samples were examined in 6 temperature steps for He, Ne, Ar, Kr, and Xe, but only the most essential data for Ne and Xe are summarized in Table 2. Our results and conclusions differ appreciably from those of Frick and Moniot (5), who studied Orgueil by their variant of the Chicago procedure.

Neon. Even our unetched residue A10.1 contains substantial amounts of Ne-E, as shown by its position below the (Ne-A)-cosmogenic line (Fig. 1). Further chemical treatments seem to remove Ne-A (and solar Ne) selectively, as shown by the drift of the points toward the Ne-E corner. Only the colloidal sample A10.2* moves upward, as expected from the well-established preference of Ne-E for non-colloidal phases (6).

The T-fractions of A10.3, though spaced 200° apart, trace out the bimodal release of Ne-E discovered by Eberhardt (6), with minimum 20/22 ratios at 600° and 1400°. The 1400° point is right inside the Ne-E region defined by Eberhardt (6), with lower 20/22 and 21/22 ratios than the most extreme samples previously known: Orgueil G4j 1230° (6) and Murchison 1C10.1400° (7). [But see also the companion abstract by Alaerts et al. (8)].

The total concentration of excess Ne²² in Orgueil A10.3 (assuming that the total neon is a mixture of Ne-A and pure Ne²²) is 48 x 10⁻⁸cc STP/g, an order

Table 1. Orgueil Residues

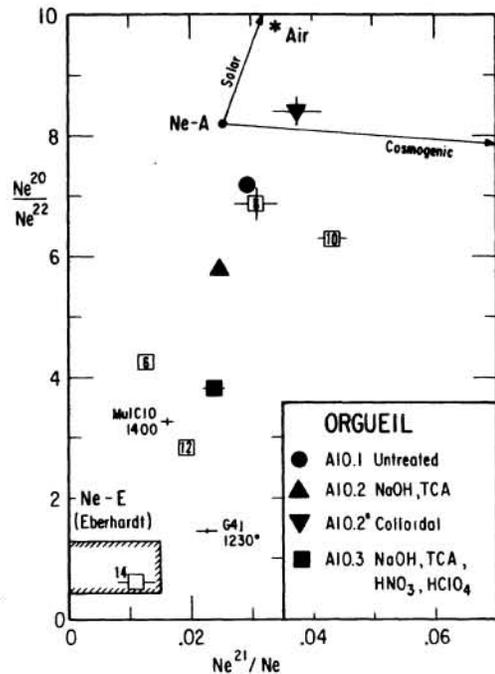
Name	% of Meteorite	From	By Treatment With	Composition ^a
A10.1	5.68	Bulk	HCl, HF	P Q Ch (~4%) Others
A10.2	2.89	A10.1	NaOH, CC1 ₂ , COOH(TCA)	P Q Ch Others
A10.2*	.32	A10.1	Colloid from A10.2	P Q Ch Others
A10.3	.48	A10.1	NaOH, TCA, HNO ₃ , HClO ₄	Ch (~40%) Others

^aP = organic polymer; Q = phase Q; Ch = chromite

Table 2. Noble Gases in Orgueil Residues (concentrations in 10⁻⁸cc STP/g)

Sample	Fraction, %c	Ne ²⁰	21/20	22/20	Xe ¹³²	130/132	134/132	136/132
A10.3	600	51	.00295 38	.2341 95	0.62	.1649 18	.3780 23	.3189 17
	800	73	.00445 50	.1454 57	0.14	.1580 20	.5024 46	.4966 67
	1000	115	.00684 30	.1589 38	0.31	.1593 28	.5094 53	.5162 43
	1200	102	.00668 49	.3520 116	0.35	.1730 23	.4824 35	.4835 42
	1400	9	.0172 39	1.59 28	0.07	.1999 62	.4022 142	.3910 55
	1600	1	.07 12	1.0 2.0	0.015	.1632 62	.3759 142	.3577 203
A10.3	Total	351	.00617 41	.2622 100	1.505	.1666 11	.4420 17	.4181 16
A10.2	Total	427	.00425 6	.1730 13	10.35	.1622 11	.3912 11	.3354 9
A10.2*	Total	875	.00443 41	.1185 37	15.97	.1620 8	.3948 14	.3407 11
A10.1	Total	377	.00406 5	.1391 8	11.90	.1608 7	.3880 12	.3308 9
W1A-2*	Total	1106	.00414 6	.1192 15	11.00	.1609 4	.4241 22	.3847 24
Bulk 8T*		52	.0217 6	.1160 15	0.96	.1604 4	.384 22	.323 24

¹Frick and Moniot (5).
²Jeffery and Anders (4); Xe isotopic ratios from Eugster et al., quoted therein.



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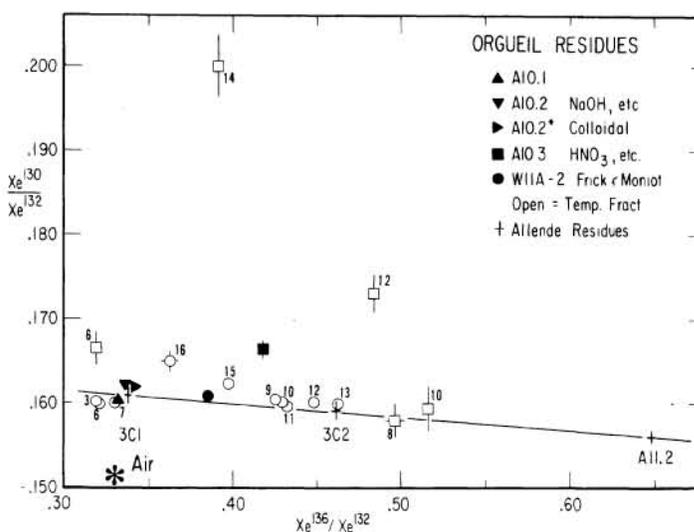
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of magnitude higher than the value for G4j, 4×10^{-8} cc/g (6). SEM examination of A10.3 showed F and Cr as the most abundant elements. Because the F almost certainly represents teflon contamination from the magnetite separation (4), the pure host phase must be even richer in Ne-E. Apparently G4j still contained >90% extraneous phases, and so the heavy irradiation inferred from radiation damage of the silicate grains (9) may not apply to the actual host phase of Ne-E. Probable host phases for Ne-E in Murchison have been discussed by Alaerts *et al.* (8); since the bimodal release is similar, it is possible, though not certain, that the same phases are present in Orgueil.

Xenon (Fig. 2). Orgueil follows the pattern of other primitive meteorites: the unetched samples A10.1 and A10.2 are dominated by trapped Xe and lie near the left corner, whereas the etched sample A10.3, after removal of Q with its trapped component, moves along the mixing line toward CCFXe on the right. The 600°, 1200°, and 1400° fractions of A10.3 fall above the mixing line, however, and apparently contain "s-process Xe", enriched in isotopes 128, 130, and 132 (7,8). Interestingly, these are the same fractions that are enriched in Ne-E (Fig. 1), and so it seems that at least one Ne-E host phase in each release peak also contains s-process Xe. Yet the correspondence is not 1:1, because the 22xs/130xs ratio varies from 8×10^2 to $>10^4$ in different Murchison fractions (8), and is 1500 and 3300 in the 600° and 1200-1400° peaks of Orgueil A10.3.

Host Phases of Noble Gases in Orgueil. Frick and Moniot (5) found substantial enrichment of CCFXe in their nominally unetched samples W11A-2 (Table 2 and Fig. 2): $136/132 = 0.385$ compared to 0.331 and 0.335 for our A10.1 and A10.2, or 0.323 for bulk Orgueil. They attribute this difference to "losses of ordinary [trapped] gases during sample preparation and storage", and note that temperatures could have exceeded 170°C after evaporation of acids. In our experience, an oxidizing agent is essential for removal of Q, and indeed, their procedure used LiNO_3 and dilute HNO_3 prior to treatment with hot HCl-HF (5). Owing to the low abundance of Q, only a trace of NO_3^- in strong HCl would suffice to oxidize it.

The Berkeley group (5,10,11) has repeatedly disputed our identification of noble-gas host phases (Q, chromite, amorphous carbon, organic polymer), and has contended that only the polymer and other, unspecified types of carbonaceous matter are involved (misleadingly called "carbon", a name reserved for the element itself). A chronic problem with the Berkeley work has been the low recovery of noble gases, owing to loss of important phases by harsh chemical treatments or inappropriate procedural steps. Examples are Ne-E and s-process Xe, which were missed entirely or almost entirely by Frick and Moniot (5), and chromite and spinel (11), as discussed in the companion abstract of Lewis *et al.* (12).



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Table 3. Fraction of Total Noble Gas in Orgueil Accounted for by Residues

Reference	Sample	HNO ₃ -Etched?	Ne ²⁰ %	Xe ¹³² %	Xe ^{136*} %	$\frac{136}{132}$
This Work	A10.1	No	41	71	113	.331
This Work	A10.3	Yes	3	1	6	.418
Frick and Moniot	W11A-2	(Yes)	17	9	51	.385

Xe^{136*} calculated as excess above Xe¹³⁶/Xe¹³² = 0.310.

This point is illustrated in Table 3, which compares the yields of 3 noble gas components in our and Frick and Moniot's Orgueil residues. Both are referenced to the bulk Orgueil analysis in Table 2. Such normalization is hard to do correctly for both samples, owing to heterogeneity of the meteorite and, especially, the NaOH-pretreatment of our material. Nonetheless, the evidence is strong that Frick and Moniot have lost phases that we were able to recover. The low 132 value suggests that they lost much of the Q, presumably by inadvertent etching with NO₃⁻. The low 20 and 136* suggests that they lost ferrichromite, presumably by dissolution in acid (12) and/or colloidal separation. The latter separation may also have caused the previously mentioned loss of the host phases of Ne-E and s-process Xe.

On the other hand, the low noble gas yield of our etched sample A10.3 also is striking. In other meteorites, Ne²⁰ and Xe^{136*} are mainly located in HNO₃-resistant phases (chromite and amorphous carbon), and hence are not greatly reduced by etching. Frick and Moniot's sample W11A-2 fits into this pattern, and shows about the right amount of 20 and 132, as well as 136/132 ratio, for an etched sample. Our sample A10.3, on the other hand, shows a far smaller recovery - about 10-15% that of W11A-2.

The reason may be the HClO₄ step (24 hours at 80°C, 1/2 hour at 100°C) added to our procedure in order to remove the polymer. As evidenced by the weight loss, it indeed destroyed much of the polymer, but in the process also removed most of the noble gases. Chromite should have survived this treatment (12), and so we conclude that a large part of the Ne²⁰ and Xe^{136*} in Orgueil either reside in a more oxidizable phase, perhaps carbonaceous - as argued by Frick and Moniot - or in very fine-grained chromite that was lost when its polymer "adhesive" was dissolved.

It is harder to prove that a certain phase does not contain noble gases than to prove that it does. One must either show that a representative sample of the phase is free of the noble gas component, or one must account for most of the component as being in other phases. We agree with Frick and Moniot that two or more kinds of carbonaceous material in Orgueil probably are major carriers of both primordial xenon and CCF xenon. We cannot agree with their unitary concept of carbonaceous material as the sole carrier, nor do we see their data as excluding Q, probably a sulfide, from being a principal carrier in the bulk meteorite and also in our residues.

References. (1) Lewis R.S. *et al.* (1975) *Science* 190, 1251; (2) Lewis R.S. *et al.* (1977) *JGR* 82, 779; (3) Srinivasan B. *et al.* (1977) *JGR* 82, 762; (4) Jeffery P.M. and Anders E. (1970) *GCA* 34, 1175; (5) Frick U. and Moniot K. (1977) *PLSC* 8, 229; (6) Eberhardt P. (1978) *PLSC* 9, *in press*; (7) Srinivasan B. and Anders E. (1978) *Science* 201, 51; (8) Alaerts L. *et al.* (1979) (abstract) *LPS* 10; (9) Audouze J. *et al.* (1976) *Astrophys. J.* 206, L185; (10) Reynolds J.H. *et al.* (1978) *GCA* 42, 1775; (11) Frick U. and Chang S. (1978) *Meteoritics* 13, *in press*; (12) Lewis R.S. *et al.* (1979) (abstract) *LPS* 10.