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The ingredients of the “Subsolar” noble gas component

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Introduction: On the basis of several experiments on separates of the EH5 chondrite St. Mark’s, we will argue that the “subsolar” noble gas component is a mixture of solar-like, Q- and terrestrial noble gases.

The subsolar noble gas component has been found, in particular, in E chondrites [1,2] but also in other meteorite classes (e.g. aubrites, CO or CH chondrites [3-5]). This component is elementally and isotopically intermediate between the common meteoritic “Q-gas” [6] and solar composition.

Experiments have never established a well-defined subsolar endmember. South Oman (EH4/5) is used as reference for subsolar element ratios [1,7]. The isotopic ratios follow the elemental trend, being intermediate between Q and solar, or even roughly solar [7].

Tab. 1 Experiments on EH5 chondrite St. Mark’s.

Sample	Method	mass [mg]	# of steps
1. “Silicates” grains <750 μm	HF/HCl online etching	238	30
2. residue from 1.	pyrolysis	88	t.b.d.
3. “Phase Q” HF/HCl residue	HNO ₃ online etching	28	23
4. aliquot from 3.	pyrolysis	4	2
5. residue from 3.	pyrolysis (2 samples)	12/17	2
6. grains <750 μm	pyrolysis “SMI” 800/1700/1750°C	81	3
7. chunk	pyrolysis “SMII” 500/800/1000/1200/1400/1600/1700°C	254	8

Experiments: Tab. 1 lists the experiments on St. Mark’s undertaken so far [8,9]. Experiment no. 1 is the first ever online etch analysis of a meteoritic bulk sample. The phase Q-rich residue remaining after online etching with HF/HCl will be measured shortly.

Results: Fig. 1 shows the He/Ar and Ne/Ar ratios. The first steps of the “silicates” etch run reveal a mixture of air and Q-like composition. More severe etching releases noble gases displaying a mixture of Q-gas and traces of unfractionated solar wind. Data points for thermal extractions of St. Mark’s [10, this work] for comparison indicate the impressive high-resolution capabilities of the online etch technique.

The observed traces of solar-like gas are not mimicked by radiogenic ⁴He fortuitously released in suitable amounts, because ³He indicates a similar release

of solar gases. Fig. 2 shows the ³He/²¹Ne and ²²Ne/²¹Ne ratios. Again, many data points of the “silicates” etch run lie on a mixing line leading to unfractionated SW composition. Here, the other endmember composition is the cosmogenic component due to the small abundance of ³He and ²¹Ne in the Q-gas [6]. Traces of solar-like noble gases could even be found for the heavier noble gases Ar-Xe (not shown).

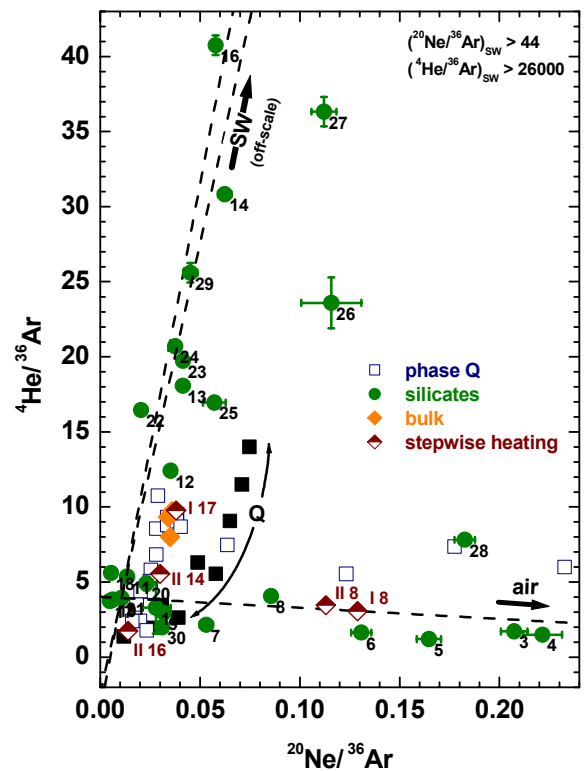


Fig. 1 He/Ar and Ne/Ar in St. Mark’s. The etch data follow the sequence air - Q - SW. The stepwise heating data show, less pronounced, a similar trend. Q data: [6]; SW-range: [15].

The etching of the acid-resistant residue shows that phase Q also trapped small amounts of solar noble gases. In both figures, the data points of the “phase Q” run plot in the region between Q-like and solar composition. The elemental ratios of phase Q (Fig. 1) roughly lie on two-component-mixing lines. This originally led us to estimate a “subsolar” composition from phase Q [8]. However, in view of the limited spread of the data compared to that of possible endmembers and the more

pronounced data pattern in the "silicates" etch run, these trends were probably misleading.

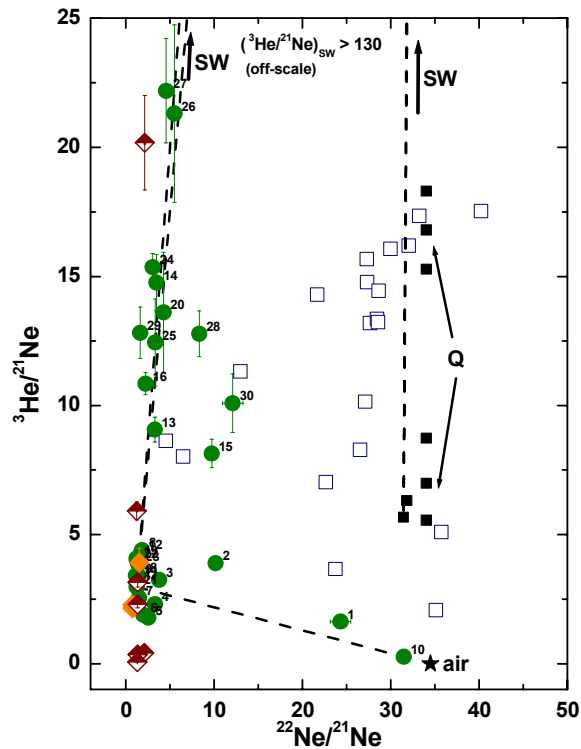


Fig. 2 This $^3\text{He}/^{21}\text{Ne}$ vs. $^{22}\text{Ne}/^{21}\text{Ne}$ plot of St. Mark's also suggests an admixture of solar gas to the usual Q-gas and a cosmogenic component, represented by the bulk measurements. See Fig. 1 for legend. Q data: [6]; SW-range: [15].

Interestingly, the stepwise heating experiment on the bulk sample of St. Mark's released the noble gases similarly to the online etch experiment, though much less well resolved. A comparable release sequence air - Q-like - solar has earlier been observed so far only for the Ar/Xe and Kr/Xe ratios of a stepwise heating experiment on the EH4 chondrite Abee [11].

The minerals most susceptible to HF vapor also lose their gas inventory already at low temperatures. The first noble gas component released in both stepwise measurements of bulk St. Mark's (etching and heating) is unfractionated air. Thus, it does not originate from the acid.

Discussion: Based on our stepwise etch experiments, we conclude that the so-called subsolar noble gas component actually is a mixture of typical Q-like noble gases with tiny amounts of solar gases plus terrestrial contamination. In view of the lack of evidence for any well-defined subsolar endmember composition in the literature and given the considerable spread of the data measured in E chondrite bulk [1,10] and chondrule samples [12], all lying within the region defined

by the three endmember components mentioned above, we further infer that the subsolar gas component does not exist.

The release characteristics of the solar gases from both silicates and phase Q indicate that the solar noble gases most likely have been trapped prior to the accretion of the precursor material. The noble gases compositionally closest to solar were released after several weeks of severe etching. In contrast, regolithic samples release their trapped solar gases, which are located in the uppermost few hundred nanometers of a mineral grain, mostly in the very first steps of an etch run [13].

The unfractionated air most likely has been introduced in minerals newly formed during the residence of the E chondrites on Earth. These meteorites show superficial weathering almost immediately after their fall. Reduced E chondrites contain large amounts of metallic iron that can transform into FeO in a terrestrial environment, thus trapping unfractionated air. This is not comparable to the adsorption mechanism that enriches terrestrial Kr and Xe in achondrites [3].

Conclusions: Our results reveal that the assumption of an independent "subsolar" component, mainly present in E chondrites, is not necessary to explain the data. High-resolution stepwise etching experiments show that the subsolar component consists of tiny amounts of solar gases plus usual Q and terrestrial noble gases. Implications of the presence of - most likely - primordially trapped solar noble gases in meteorites are discussed in a companion abstract [14].

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