

DOES VENUS' ATMOSPHERE CONTAIN A TERRESTRIAL-LIKE COMPONENT?

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A summary of abundances of the volatile elements C, N, and the noble gases for the terrestrial planets, the sun, and carbonaceous meteorites (Fig. 1) shows a similarity for Venus and Earth, except that Ne and ^{36}Ar abundances on Venus are nearly two orders of magnitude higher than for the Earth. It has been suggested that the high abundance of Ne and Ar on Venus is due to an acquired solar wind component (1,2,3). In order to understand the origin of volatiles in the atmospheres of the terrestrial planets and the relationship of these volatiles to other volatile reservoirs such as the sun and meteorites, it is important to know whether Venus, Earth, and Mars contain a common volatile component. Unfortunately, the isotopic compositions of volatiles in Venus' atmosphere are essentially unknown and thus cannot be used for comparison.

Three-element correlation plots have been used extensively in geochemistry to identify mixtures of geochemical components. We have used this technique for N, C, and the noble gases to compare the volatile components of Venus, Earth, and Mars with solar composition and volatiles found in carbon-rich meteorites, and with various physical processes that may have mass fractionated these volatile reservoirs. Fig. 2 gives, as examples, the Xe/Ar-N/Ar and Kr/Ar-N/Ar three-element correlation plots; other plots using C/Ar and Ne/Ar have also been examined. The solid lines are mixing lines (curved on these log-log plots) between solar and carbonaceous and solar and Earth compositions, and the tick marks on these lines show various component mixtures in units of ten, e.g., 100 parts solar to 1 part Earth. The lunar point represents solar gases fractionated during implantation into silicate surfaces and may more accurately represent the composition of solar gases on Venus.

We utilized various three-element correlation plots to examine several possible explanations for the volatiles in Venus' atmosphere, e.g., solar-meteorite and solar-Earth mixtures, lunar-solar and lunar-Earth mixtures, extremely fractionated solar, and low-temperature fractionation produced by adsorption and clathrate formation. Table 1 is a truth table that summarizes conclusions. C on Venus is consistent with a solar-Earth or lunar-Earth mixture but not with two component mixtures involving meteorite volatiles. N is consistent with a variety of possible mixtures or with low-temperature processes that concentrate volatiles. Kr on Venus is not consistent with a solar-meteorite mix. Xe on Venus is consistent with two component mixtures only if its abundance is actually several factors lower than the upper limit reported. Ne appears consistent only with an extreme lunar-like fractionation of solar composition. N, Ar, Kr, and Xe would be consistent with all of Venus' volatiles having been derived from a lunar-like, but extremely fractionated solar component, but C would be in excess relative to this fractionation, and Ne, deficient. We suggest that the most consistent explanation of the volatiles in Venus' atmosphere is that they are a mixture of an Earth-like component, which contributes most of the C, N, and Xe, and a lunar-like, fractionated solar component contributing most of the Kr and nearly all of the Ar and Ne. This suggests that Venus and the Earth contain a common volatile component in comparable concentrations. Volatiles in meteorites are apparently enriched in C, N, and Xe compared to Ar and Kr, possibly as a result of low-temperature processes such as adsorption and clathrate formation (4), whose composition at 100° Kelvin tend to plot on the opposite side of the meteorite data from Earth volatiles.

1) M. McElroy & M. Prather, Nature 293, 1981, p.535. 2) G. Wetherill, Icarus 46, 1981, p.70. 3) J. Pollack & D. Black Icarus 51, 1982, p.169. 4) G. Sill & L. Wilkening, Icarus 33, 1978, p.13.

Fig. 1 Noble gas abundances are in cm^3 per gram of planet or meteorite; C and N abundances are in moles per gram of planet or meteorite; Mars and Venus represent the atmosphere only, whereas Earth is the estimated whole-planet inventory. The solar value is arbitrarily normalized to an ^{36}Ar value of 10^{-7} .)

Fig. 2 Kr/Ar-N/Ar and Xe/Ar-N/Ar three-element correlation plots for Earth, Venus, Mars, average carbonaceous chondrites (C), the sun, and solar wind implanted into the lunar surface. Solar-Earth and solar-meteorite mixing lines are shown, as are low-temperature clathrates (diamond) and adsorbed gases (dashed line). The range of N/Ar values for Mars give the actual measured ratio and two "corrected" N abundances with the assumption that a large fraction of the N has been lost from the Martian atmosphere.

Table 1. TRUTH TABLE FOR MODELS OF ORIGIN OF VENUS' ATMOSPHERE

ARE N, C, & NOBLE GASES CONSISTENT WITH:	ELEMENT RATIO FROM 3-ELEMENT PLOTS				
	C/AR	N/AR	XE/AR	KR/AR	NE/AR
MIX SOLAR + EARTH	YES	YES	IF 0.1 XE	YES	NO
MIX SOLAR + MET.	NO	YES	IF 0.1 XE	NO	NO
FRACTIONATED SOLAR AS LUNAR	NO	IF excess	IF EXTREME	IF EXTREME	NO ? deficient
MIX LUNAR + EARTH	YES	YES	IF 0.3 XE	YES	NO
MIX LUNAR + MET. LOW-TEMP. (<200°K)	NO	YES	IF 0.3 XE	YES	NO
ADSORPTION	--	YES	IF 0.5 XE	YES	NO
CLATHRATES	NO	YES	YES	NO	?

