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Helium on venus: implications for uranium and thorium.

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24. In some temperature steps the quantities of carbon were too small for conventional isotopic measurement, but still above blank level. Such fractions were analyzed by isotope dilution, by first measuring the amount of CO_2 on a capacitance manometer and then mixing the sample with a metered amount of CO_2 of known isotopic composition. The reproducibility of this technique, as tested with CO_2 of known isotopic composition, is $< \pm 10$ per mil for a sample size of 100 ng.
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29. The small amount of dichromate-soluble Xe is isotopically similar to the surface-sited HNO_3-soluble Xe and is simply a remnant of it. Other experiments (*2, 3, 21*) show that it can be removed by prolonged treatment with HNO_3 or H_2O_2 with little loss of carbon. Hence this component does not belong to the dichromate-degradable carbon.
30. This jump—a hint of which was seen in earlier studies (*2, 3, 31*)—may be caused by a trace of heavy carbon associated with *s*-Xe (and Ne-E?). Though stepped heating failed to detect these noble gas components in Allende (*21, 32*), stepped combustion revealed minor amounts of both (*33*). Unfortunately, we took no isotopic data for B1B after the main peak at 550°C, and hence do not know whether the heavy carbon survived the dichromate treatment.
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39. We thank L. Alaerts for preparing the 2C10 samples, I. P. Wright for discussions, and Tang Ming for assistance with the figures. An anonymous referee provided a most helpful, constructively critical review. Supported in part by NASA grant NGL-14-001-010 and the Science and Engineering Research Council.

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Helium on Venus: Implications for Uranium and Thorium

Abstract. *Helium is removed at an average rate of 10^6 atoms per square centimeter per second from Venus's atmosphere by the solar wind following ionization above the plasmapause. The surface source of helium-4 on Venus is similar to that on Earth, suggesting comparable abundances of crustal uranium and thorium.*

Studies of helium in Earth's atmosphere have a long and checkered history (*1–4*), providing valuable information on escape, on the composition of the solid body, and on physical processes regulating release of volatiles from the interior. The atmosphere contains 5.3×10^{-6} by volume of ^{4}He, formed by decay of uranium and thorium in crustal rocks, and 6.6×10^{-12} by volume of ^{3}He, for the most part primordial, emanating from tectonically active regions of the sea floor (*3*).

Helium escapes from the atmosphere predominately by nonthermal mechanisms, mainly as He^+ along magnetic field lines open to the interplanetary medium at high latitudes—the polar wind (*4*). Escape is efficient and must balance production on time scales of the order of 10^6 years. The rate of production of ^{3}He, 4 atoms per square centimeter per second, may be derived from measurements of the gas dissolved in the ocean, with independent information on the oceanic mixing time (*5*) and allowing for a small additional source from cosmic rays. The rate of escape, or equivalently production, of ^{4}He may be obtained by scaling results for ^{3}He, using the observed ratio of the gases in the atmosphere and correcting for minor enrichment of ^{3}He above the turbopause (*4, 6*). The source derived in this fashion, 2×10^6 cm^{-2} sec^{-1}, is in good agreement with limits established by MacDonald (*2*) from considerations of the planetary heat flux and available data for uranium, thorium, and potassium.

Helium was first observed as a component of Venus's atmosphere by Mariner 10 (*7*), and more extensive measurements were made by Pioneer. The abundance of ^{4}He in the upper atmosphere is known quite accurately (±20 percent) from mass spectrometric measurements on the Pioneer orbiter (*8*) and bus (*9*). Combined data from the orbiter, bus, and probe (*10*) indicate a mixing ratio for the gas in the bulk atmosphere of 1.2×10^{-5} with an uncertainty of about a factor of 2.

Helium ionized above the plasmapause on Venus is swept off by the solar wind, as discussed by Dessler (*11*). The ionization rate may be calculated as described by McElroy *et al.* (*12*) for oxygen. Using ionization rates for helium of 3.4×10^{-7} sec^{-1} for photoionization (*13*) and 6.4×10^{-7} sec^{-1} for electron impact (*14*), and measured concentrations of ^{4}He, we estimate a loss rate of 10^6 cm^{-2} sec^{-1}. We assume that loss of helium from the nightside is trivial and use data from Brace *et al.* (*15*) to define an empirical model for the height of the plasmapause. Collisions between hot oxygen atoms and helium were shown by Knudsen (*16*) to be important for escape of helium from Mars. They are not directly important for escape of helium from Venus but contribute an additional 20 percent to the abundance of helium above the dayside plasmapause. The loss rate for helium may be defined to about the same precision as that for oxygen; in both cases the uncertainty is related primarily to definition of the mean position of the plasmapause. McElroy *et al.* (*12*) argued that the momentum flux of solar wind is balanced mainly by addition of mass as O^+, allowing an independent estimate for escape of oxygen. These considerations suggest that escape rates for oxygen, and by extension for ^{4}He, are determined to an accuracy of about ±30 percent.

The rate for escape of ^{4}He derived here (10^6 cm^{-2} sec^{-1}), combined with the abundance inferred from Pioneer (1.8×10^{22} cm^{-2}), indicates a lifetime for ^{4}He in Venus's atmosphere of

6×10^8 years, about 300 times longer than that for Earth. The longer lifetime for Venus reflects the higher abundance of ^{4}He (factor of 100) and the lower escape efficiency (factor of 3). Escape from Venus is limited by the relatively small quantities of gas which extend above the plasmapause.

Venus has lost a quantity of ^{4}He equivalent to 1.8×10^{22} cm^{-2} over the past 6×10^8 years. The present atmosphere is unlikely to retain appreciable quantities of its initial helium—escape would lead to a reduction of the primordial abundance by a factor of 5×10^{-4} (*17*). Contemporary escape should mirror the average quantity of ^{4}He released by the solid planet over the past 10^9 years. The necessary source would be supplied by decay of uranium and thorium if the abundance of these elements in Venus's lithosphere were similar to that for Earth (*18*).

Venus's atmosphere also includes measurable quantities of ^{40}Ar, formed by decay of ^{40}K. The relative abundances of ^{40}Ar in the terrestrial and Venus atmospheres suggest that the averaged source of ^{40}Ar at Venus's surface is less than that for Earth by about a factor of 4 (*19, 20*). The lower release rate could reflect either smaller abundances of ^{40}K or less efficient mechanisms for transfer of gas to the atmosphere. Measurements by Venera 13 and Venera 14 (*21*) suggest that potassium in Venus's surface material is similar to that for typical terrestrial basalts. In this case the lower abundance of ^{40}Ar on Venus could be due to less efficient degassing, perhaps reflecting a reduced role for tectonic activity in the presence of high surface temperatures (*22*). However, we might expect a differential effect for helium. Helium can escape by molecular diffusion from a depth of 1 km on Venus, aided by the high surface temperature, while the corresponding diffusion length for Earth is only 400 cm (*23*).

In summary, Venus's atmosphere contains 160 times more ^{4}He than the atmosphere of Earth. The source of ^{4}He is similar in magnitude for both planets, suggesting comparable abundances of uranium and thorium. Independent arguments suggest that the two planets have similar abundances of potassium, and it follows that the magnitude of the planetary heat flux should be similar for both bodies. From these results, together with information for nitrogen (*24*), carbon, water (*25*), and noble gases (*19*), we conclude that Venus and Earth had similar origins. The high concentration of primordial noble gases on Venus is attributed to capture of solar wind materials prior to planetary formation (*19, 26*); the low abundance of H_2O is due to escape of H and O (*12, 25, 27*) evidenced by enrichment of contemporary deuterium (*28*).

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Desickling of Sickled Erythrocytes by Pulsed Radio-Frequency Field

Abstract. *Electric fields were found to deform sickled erythrocytes. When the intensity of applied fields exceeded a threshold value, sickled erythrocytes transformed into a spherical shape. Prolonged application of the field usually caused hemolysis of erythrocytes. Deformation of red blood cells could be partly reversed if the field was turned off at an early stage. The cause of desickling may be the interaction of the field with the erythrocyte membrane and also with gelled intracellular hemoglobin S molecules.*

In patients with sickle cell anemia, red cell sickling is caused by the intracellular polymerization of deoxy-hemoglobin-S molecules. This polymerization can be inhibited by chemicals that interact with the hemoglobin molecule (*1, 2*) or with the erythrocyte membrane (*3, 4*). Chemicals such as cetiedil interact with the red cell membrane to increase water intake and inhibit red cell sickling at a concentration of 1 to 3 percent of intracellular hemoglobin (*3–5*).

We report a method for reversing red cell sickling without using chemicals. We found that sickled cells were converted within several minutes to a spherical shape by the application of pulsed radio-frequency (RF) fields. Experiments were carried out by placing a suspension of sickled red blood cells in an isotonic saline solution between two parallel Pt-Ir wires (see legends to Figs. 1 and 2 for details). We chose a short pulse width of 5 msec with an interval of 1 second to