The measuring technique for diffusion coefficients which is outlined in this work is believed to be very suitable for routine analyses of many binary systems. It is of course necessary that \( \frac{\Delta H}{\Delta C} \) is not too small as in most isotopic mixtures. If the “dropped crystal technique” cannot be used it may be possible to design an apparatus where the diffusing substance is transferred by other means to the bottom of the cell even at high temperatures.

Acknowledgement

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On Noble Gas Anomalies in the Great Namaqualand Troilite

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The abundances and isotopic composition of the stable noble gases were measured in a troilite nodule from the Great Namaqualand fine octahedrite. Helium, neon and argon show a significant spallation component. The major anomalies in krypton and xenon are from neutron capture on selenium and tellurium and from the decay of extinct \( ^{129}I \). The abundances of tellurium, iodine and uranium in the troilite were determined by neutron activation analyses and compared with the xenon anomalies. The results indicate that part of the excess \( ^{129}Xe \) is from neutron capture on tellurium and the remainder is due to the retention of radiogenic \( ^{129}Xe \) from the decay of extinct \( ^{129}I \), about 200 million years after an initial \( ^{129}I/^{127}I = 3 \times 10^{-3} \).

Although there have been many reports on the isotopic composition of the heavy noble gases in stone meteorites, relatively few studies have been reported on the abundances of the heavy noble gas isotopes in iron meteorites. Reynolds \(^1\) reported the abundances of four xenon isotopes in Sardis troilite and three xenon isotopes in Sardis iron. Only recently have complete xenon and krypton spectra been reported for two iron meteorites; Costilla Peak iron \(^2\) and Canyon Diablo graphite \(^3\).

The isotopic anomalies observed in these two samples showed remarkably few similarities. Both the xenon and krypton spectra in Costilla Peak were characterized by a large spallation component. Radiogenic \( ^{129}Xe \) could not be positively identified, but an upper limit of \( 2.2 \times 10^{-13} \) cc STP radiogenic \( ^{129}Xe \) per gram of Costilla Peak iron was established. In contrast to this the xenon and krypton spectra in Canyon Diablo graphite showed only a small spallation component but contained major anomalies due to neutron capture reactions on bromine and iodine. The amount of radiogenic \( ^{129}Xe \) in Canyon Diablo graphite, \( 8.5 \times 10^{-18} \) cc STP per gram, was greater than had been reported in any stone meteorite except Renazzo and Abee.

The iodine abundance have been measured for both the Sardis troilite \(^4\) and the Canyon Diablo graphite \(^5\). The ratio of radiogenic \( ^{129}Xe \) to iodine in the graphite is about 350 times the value of this ratio in the troilite. This suggests that the Canyon Diablo graphite began to retain the gaseous decay product of 17 million year (m. y.) \( ^{129}I \) about the same time as the chondrites, but almost 150 m. y. before the Sardis troilite.

Due to the scarcity of noble gas data on the iron meteorites and the great differences in the krypton and xenon anomalies in the above-mentioned reports, it was decided to investigate the noble gases and the tellurium, iodine and uranium abundances from a single troilite nodule. The sample used for this study was provided by the museum of the University of Missouri at Rolla.

Hey \(^6\) lists fifteen synonyms which have been used for the Great Namaqualand meteorite. Wasson \(^7\) determined the concentration of Ga and Ge in this meteorite (under the synonym, Gibeon) and classi-

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fied it as a member of the Group IVa fine octahedrites. According to Voshage, most members of this group were produced in a single collision about 400 \times 10^6 years ago.

**Experimental**

1. **Noble Gases**

   A troilite nodule weighing about five grams was taken from a cut surface of the meteorite. A piece of this nodule weighing 218.4 mg was mounted in a side-arm chamber so that it could be dropped into a molybdenum crucible for gas extraction. The sample was heated at \(\approx 100 \, ^\circ\text{C}\) overnight to remove surface contamination and then dropped into the previously outgassed molybdenum crucible. The sample was melted by radiofrequency induction heating and the evolved gases cleaned on titanium at 850 \(^\circ\text{C}\). The noble gases were separated into four fractions by adsorption on charcoal and analyzed in the following order: helium and neon, argon, krypton, and finally xenon.

   The gases were analyzed statically in a Reynolds' type 4.5 inch 60° sector mass spectrometer. The spectrometer was calibrated before and after the experiment by subjecting air spikes of approximately 0.01 cc STP to the same procedure of analysis as used for the sample. The amount of each noble gas in the sample was obtained by comparing the peak heights from the sample with those from the air spikes. The isotopic compositions reported here were corrected for mass spectrometer memory by extrapolating the observed ratios to the start of the analysis. The errors reported in the isotope ratios are one standard deviation (\(\sigma\)) from the least squares line through the observed ratios and do not take into account any systematic error from background. Results from blank analyses using the same procedure for the hot molybdenum crucible showed no significant contamination peaks in the noble gas region, except at mass 78.

2. **Tellurium, Iodine and Uranium**

   The tellurium, iodine and uranium contents of Great Namaqualand troilite were determined by neutron activation analyses. The chemical procedure was essentially identical to that reported by Coles and Anders and by Clark, Rowe, Ganapathy, and Kuroda. The samples were irradiated with two aqueous monitors of each of the following salts: KI, Te(N\(_4\)O\(_4\))\(_4\) and UO\(_2\)(NO\(_3\))\(_2\). The irradiation was conducted in a local reactor at a flux of about \(5 \times 10^{12} \, \text{n/cm}^2/\text{sec}\).

Approximately 20 mg of iodine carrier was added to each sample and monitor. Following several cycles of iodine extraction into carbon tetrachloride and back-extraction into aqueous NaHSO\(_4\), the iodine was precipitated as AgI, filtered, dried and mounted on 2 inch stainless steel planchets for proportional counting. Blanks containing distilled water sealed in the same polyethylene capsules as used for samples and monitors were analyzed with each experiment.

The AgI precipitates were counted for gross \(\beta\)-activity in a gas-flow end window proportional counter having a background of 12 counts per minute. The abundances of iodine and uranium were determined from two samples irradiated for 25 minutes. Due to the relatively small neutron capture cross-section of Te\(_{136}\) and the long half-period of I\(_{131}\), the tellurium abundance was determined on a separate sample which had undergone a two hour irradiation.

**Results and Discussion**

1. **Helium, Neon and Argon**

   The abundances and isotopic composition of helium, neon and argon are shown in Table 1. The He\(^3\)/He\(^4\), Ne\(^{20}\)/Ne\(^{21}\) and Ar\(^{38}\)/Ar\(^{36}\) ratios are similar to those observed in the iron phase of meteorites and attributed to cosmic-ray induced spallation reactions.

   The Ar\(^{38}\)/Ar\(^{36}\) ratio in the troilite is slightly smaller than any of the values reported by Siger and Nier in an analysis of 23 different iron meteorites. This may be due to atmospheric contamination or to secondary neutron capture reactions on chlorine. The Ar\(^{40}\)/Ar\(^{36}\) value is appreciably larger than any of the values reported by Voshage, Eberhardt, Geiss and H. Lutz, Earth Science and Meteorites, compiled by J. Geiss and E. D. Goldberg, North-Holland Publ. Co., Amsterdam 1963.
than the ratio produced by spallation. This excess $\text{Ar}^{40}$ may result from the decay of $\text{K}^{40}$ in the troilite or from atmospheric contamination.

The likelihood that atmospheric contamination is responsible for the excess $\text{Ar}^{40}$ can be examined by comparing the amount of $\text{Ar}^{40}$ with that expected from the potassium content of the troilite. As will be noted later, the troilite has retained radiogenic $\text{Xe}^{129}$ from extinct $\text{Xe}^{129}$ and may therefore be expected to have retained an appreciable fraction of its radiogenic $\text{Ar}^{40}$. By assuming that all of the radiogenic $\text{Ar}^{40}$ has been retained in the troilite and that the potassium has the same isotopic composition as terrestrial potassium, it can be shown that the troilite would have to contain a minimum of 70 ppm K in order to have produced the observed $\text{Ar}^{40}$ over the past 4.55 billion years. Since this minimum potassium content is sizeably larger than the potassium content in troilite from Canyon Diablo, Odessa or Xiquipilco, it seems likely that atmospheric contamination is responsible for most of the $\text{Ar}^{40}$ shown in Table 1.

A maximum spallation $\text{Ar}^{38}/\text{Ar}^{36}$ ratio for the troilite can be obtained by assuming that all of the $\text{Ar}^{40}$ is due to atmospheric contamination. When corresponding amounts of atmospheric $\text{Ar}^{38}$ and $\text{Ar}^{36}$ are subtracted from the values shown in Table 1, there results a maximum value of spallation $\text{Ar}^{38}/\text{Ar}^{36} = 1.51$. Since this value is equal to the lowest spallation $\text{Ar}^{38}/\text{Ar}^{36}$ value reported by Signer and Nier, an argon component due to neutron capture on chlorine cannot be positively identified.

The $\text{Ne}^{21}/\text{Ar}^{38}$ ratio in the troilite is about a factor of three larger than that observed in iron meteorites. This is due to the contribution of both iron and sulfur to the production of cosmogenic neon. If the troilite is assumed to be pure FeS, then the difference in the $\text{Ne}^{21}/\text{Ar}^{38}$ ratios in the iron and the troilite phases can be used to calculate the relative cross sections of sulfur and iron for the production of $\text{Ne}^{21}$, $\sigma_{\text{Fe}^{21}}/\sigma_{\text{Fe}^{31}}$.

$$\left(\frac{\text{Ne}^{21}}{\text{Ar}^{38}}\right)_{\text{Troilite}} = \left(\frac{\sigma_{\text{Fe}^{21}} + \sigma_{\text{Fe}^{31}}}{\sigma_{\text{Fe}^{31}}}\right)_{\text{Iron}} \approx 0.20. $$

In the analyzes of 21 iron meteorites, Signer and Nier found $\left(\frac{\text{Ne}^{21}}{\text{Ar}^{38}}\right)_{\text{Iron}} \approx 0.20$. This value of $\sigma_{\text{Fe}^{21}}/\sigma_{\text{Fe}^{31}}$ in Eq. (1) yields $\sigma_{\text{Fe}^{21}}/\sigma_{\text{Fe}^{31}} = 2.2$, i.e., cosmic rays on sulfur in this troilite nodule were 2.2 times as effective in producing $\text{Ne}^{21}$ as were cosmic rays on iron.

Begemann has measured the abundances of cosmogenic helium, neon and argon in troilite nodules of Sardis, Mt. Edith and Odessa. As in this troilite nodule from Great Namaqualand, the $\text{He}^{3}/\text{Ne}^{21}$ and $\text{Ar}^{38}/\text{Ne}^{21}$ ratios were appreciably smaller than in the iron phase, but the $\sigma_{\text{Fe}^{21}}/\sigma_{\text{Fe}^{31}}$ ratios were larger than in Great Namaqualand. In Table 2 the relative abundances of $\text{He}^{3}$, $\text{Ne}^{21}$ and $\text{Ar}^{38}$ in these troilite nodules are compared with the relative cross sections for the production of $\text{Ne}^{21}$ from sulfur and iron.

Although the low $\text{He}^{3}/\text{Ne}^{21}$ ratio in the Great Namaqualand troilite may be due to preferential loss of helium during the twelve hour preheating of the sample to $\approx 100 \, ^\circ\text{C}$, the correlation of the $\text{He}^{3}/\text{Ne}^{21}$ ratio with the ratio of the $\text{Ne}^{21}$ production cross sections, $\sigma_{\text{Fe}^{21}}/\sigma_{\text{Fe}^{31}}$, suggests that the relatively low helium content may reflect the depth of the sample below the surface during exposure to cosmic rays. Hey indicates that over 14,600 kg of Great Namaqualand have been recovered. This suggests that the preatmospheric mass may have been large enough to have shielded part of the sample from the primary cosmic ray flux and thus alter the relative production rates of the different noble gases.

The cosmic ray exposure age of the Great Namaqualand meteorite has not been reported. Voshage has determined the $\text{K}^{41}/\text{K}^{40}$ exposure age on 60 iron meteorites and shown that most of the fine octahedrites of the Ga-Ge-Group IVa were produced in a single collision about $4 \times 10^{8}$ years ago. This exposure age together with the noble gas abundances listed in Table 1 indicate that the production rates

<table>
<thead>
<tr>
<th>$\text{He}^{3}/\text{Ne}^{21}$</th>
<th>$\text{Ar}^{38}/\text{Ne}^{21}$</th>
<th>$\sigma_{\text{Fe}^{21}}/\sigma_{\text{Fe}^{31}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trolite Phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Namaqualand</td>
<td>2.8</td>
<td>1.53</td>
</tr>
<tr>
<td>Sardis $^{15a}$</td>
<td>11.6</td>
<td>4.3</td>
</tr>
<tr>
<td>Mt. Edith $^{15a}$</td>
<td>15.3</td>
<td>0.57</td>
</tr>
<tr>
<td>Odessa $^{15a}$</td>
<td>15.9</td>
<td>9.4</td>
</tr>
<tr>
<td>Iron Phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sardis $^{15a}$</td>
<td>4.63</td>
<td></td>
</tr>
<tr>
<td>Mt. Edith $^{15a}$</td>
<td>71</td>
<td>4.57</td>
</tr>
<tr>
<td>Odessa $^{11}$</td>
<td>93</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Table 2. Cosmogenic gases in troilite and the cross sections of sulfur and iron for producing $\text{Ne}^{21}$.


$^{15a}$ F. Begemann, Z. Naturforsch. 20 a, 950 [1965].
of He\textsuperscript{3}, Ne\textsuperscript{21} and Ar\textsuperscript{38} in the troilite were 26 \times 10^{-10}, 10.2 \times 10^{-10} and 15.8 \times 10^{-10} cc STP per gram per million years. This production rate for He\textsuperscript{3} is not exceptionally low compared to production rates calculated by Schaeffer and Fisher\textsuperscript{16} and by Sinner and Nier\textsuperscript{11}, but the production rates of both Ne\textsuperscript{21} and Ar\textsuperscript{38} are much higher than the production rates reported in the iron phase of meteorites\textsuperscript{11,12,16}. It should be noted, however, that the exposure age of Great Namaqualand could be substantially greater than 400 million years since one member of the IVa group studied by Voshage\textsuperscript{8} had an exposure age of 745 million years.

A determination of the Cl\textsuperscript{36} activity in the Great Namaqualand would make it possible to determine the actual cosmic ray flux on this sample and would also test the hypothesis of Schaeffer and Fisher\textsuperscript{16} that the meteorites with low Cl\textsuperscript{36} activity have low He\textsuperscript{3}/Ar\textsuperscript{38} ratios.

2. Krypton

The abundance and isotopic composition of krypton in the troilite are compared with krypton from troilite and graphite nodules of Canyon Diablo in Table 3. The isotopes are normalized to Kr\textsuperscript{86} because this isotope has essentially no spallation component\textsuperscript{2,17}. The excess of each of the light krypton isotopes relative to atmospheric krypton are shown in Table 4, where

\[
\delta_i = \left(\frac{Kr_i}{Kr_{86}}\right)_{\text{Meteorite}} - \left(\frac{Kr_i}{Kr_{86}}\right)_{\text{Atmosphere}}. \tag{2}
\]

Eq. (2) will yield negative anomalies for samples such as Canyon Diablo graphite which contains an excess of Kr\textsuperscript{86} and a relatively small spallation component.

<table>
<thead>
<tr>
<th>meteorite</th>
<th>Kr\textsuperscript{80}</th>
<th>Kr\textsuperscript{82}</th>
<th>Kr\textsuperscript{83}</th>
<th>Kr\textsuperscript{84}</th>
<th>investigator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Namaqualand troilite</td>
<td>0.158 \pm 0.007</td>
<td>0.044 \pm 0.031</td>
<td>0.320 \pm 0.013</td>
<td>0.071 \pm 0.022</td>
<td>This work</td>
</tr>
<tr>
<td>Canyon Diablo troilite</td>
<td>0.046</td>
<td>0.023</td>
<td>0.064</td>
<td>-0.052</td>
<td>Clark and Thode\textsuperscript{18}</td>
</tr>
<tr>
<td>Canyon Diablo graphite</td>
<td>0.302</td>
<td>0.100</td>
<td>-0.010</td>
<td>-0.062</td>
<td>Alexander and Manuel\textsuperscript{3}</td>
</tr>
<tr>
<td>Costilla Peak iron</td>
<td>0.423</td>
<td>0.535</td>
<td>0.617</td>
<td>0.082</td>
<td>Munk\textsuperscript{2}</td>
</tr>
<tr>
<td>spallation krypton</td>
<td>0.495</td>
<td>0.765</td>
<td>= 1.000</td>
<td>0.63</td>
<td>Marti et al.\textsuperscript{17}</td>
</tr>
</tbody>
</table>

Table 3. Krypton from Great Namaqualand troilite and other inclusions in iron meteorites. Krypton spectrum for Canyon Diablo troilite has not been corrected for mass discrimination.

Relative to the excesses of other krypton isotopes, the troilite samples display a large excess of Kr\textsuperscript{83}. For example, the $\delta_{83}/\delta_{82}$ ratio in Great Namaqualand troilite is more than five times as large as the $\delta_{83}/\delta_{82}$ ratios in spallation krypton from the iron phase of Costilla Peak or from the Stannern achondrite. Clarke and Thode\textsuperscript{18} suggested that the excess Kr\textsuperscript{83} in Canyon Diablo troilite was produced by neutron capture on Se\textsuperscript{82}. This appears to be the most likely mechanism to account for the large $\delta_{83}/\delta_{82}$ ratio in the troilite. The high tellurium content and the excess Xe\textsuperscript{131} in the troilite, as will be discussed in the next section, suggest that the troilite contains sufficient selenium to account for the Kr\textsuperscript{83} anomaly.

It is more difficult to assign an origin to the smaller krypton anomalies at Kr\textsuperscript{80}, Kr\textsuperscript{82} and Kr\textsuperscript{84}. The $\delta_{80}/\delta_{82}$ ratio is similar to that in Canyon Diablo graphite, which has been attributed to neutron capture on bromine.\textsuperscript{3} However, the $\delta_{84}/\delta_{82}$ ratio in the troilite is larger than the spalation ratio observed

\textsuperscript{16} O. A. Schaeffer and D. E. Fisher, Nature \textbf{186}, 1040 [1960].
\textsuperscript{18} W. B. Clarke and H. G. Thode, J. Geophys. Res. \textbf{69}, 3673 [1964].
in either Stannern or Costilla Peak, and the assignment of part of the excess $^{82}\text{Kr}$ to neutron capture would require an even higher $\delta^{84}/\delta^{82}$ spallation ratio in the troilite.

There appears to be no single mechanism capable of explaining the excess $^{80}\text{Kr}$, $^{86}\text{Kr}$ and $^{84}\text{Kr}$. If there are measurement errors above the statistical errors shown in Table 4, these are most likely to affect the $\delta^{84}$ value where the excess $^{84}\text{Kr}$ amounts to only 2% of the total $^{84}\text{Kr}$. In contrast to this, the excess $^{80}\text{Kr}$, $^{82}\text{Kr}$ and $^{83}\text{Kr}$ are 55%, 6% and 33%, respectively, of each isotope’s abundance. Tentatively, it appears that neutron capture on bromine and selenium are responsible for the krypton anomalies in the Great Namaqualand troilite. Clarke and Thöde assigned the krypton anomalies in Canyon Diablo troilite to these same neutron capture reactions.

3. Xenon, Tellurium, Iodine and Uranium

The isotopic composition of xenon in the Great Namaqualand troilite is shown in Table 5. The xenon content is approximately equal to that in the iron phase of Costilla Peak, but almost a factor of 10 smaller than that in the troilite phase of Sardis. Within experimental error, the isotopic composition of xenon in the Great Namaqualand troilite is identical to the primordial xenon in Murray except at mass numbers 129 and 131. In order to determine the origin of these anomalies, the abundances of elements most likely to have contributed to the medium-weight xenon isotopes were determined by neutron activation analyses.

The iodine, tellurium and uranium abundances in the troilite are shown in Table 6. The iodine and uranium contents in the Great Namaqualand troilite are similar to those in Canyon Diablo troilite, but the tellurium content of the Great Namaqualand troilite is greater than that reported in any troilite phase by Goles and Anders. In spite of the chalcophilic nature of tellurium, Goles and Anders found the abundances of tellurium in troilite to be about equal to the tellurium content of carbonaceous and enstatite chondrites. The tellurium content in the Great Namaqualand troilite, 18 ppm, corresponds to an atomic ratio Te/S = $1.2 \times 10^{-5}$ if the troilite is assumed to be pure FeS. This value is in close agreement with the cosmic Te/S ratio reported by Suess and Urey.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Tellurium (ppm.)</th>
<th>Iodine (ppb.)</th>
<th>Uranium (ppb.)</th>
<th>Investigator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Namaqualand</td>
<td>$18 \pm 5$</td>
<td>$90 \pm 30$</td>
<td>$2.1 \pm 0.5$</td>
<td>this work</td>
</tr>
<tr>
<td>Canyon Diablo</td>
<td>5.0</td>
<td>62</td>
<td>3.5</td>
<td>Goles and Anders</td>
</tr>
<tr>
<td>Sardis</td>
<td>7.8</td>
<td>3590</td>
<td>6.5</td>
<td>Goles and Anders</td>
</tr>
<tr>
<td>Grant</td>
<td>2.4</td>
<td>24</td>
<td>6.5</td>
<td>Goles and Anders</td>
</tr>
<tr>
<td>Toluca</td>
<td>1.7</td>
<td>1030</td>
<td>10</td>
<td>Goles and Anders</td>
</tr>
<tr>
<td>Soroti</td>
<td>1.2</td>
<td>50</td>
<td>17</td>
<td>Goles and Anders</td>
</tr>
</tbody>
</table>

Table 6. Tellurium, iodine and uranium in the troilite phase of iron meteorites.
From the data in Table 5 it appears that the xenon in the Great Namaqualand troilite has been enriched in Xe$^{131}$ and Xe$^{129}$. Relative to the xenon spectrum of Murray, there are $1.5 \times 10^{-12}$ cc STP excess Xe$^{131}$ and $8.8 \times 10^{-12}$ cc STP excess Xe$^{129}$ per gram of troilite. Since fission would also produce excesses at Xe$^{132}$, Xe$^{134}$ and Xe$^{136}$, the anomalies in the troilite are probably the result of nuclear reactions on tellurium and/or the in situ decay of extinct I$^{129}$.

Thermal neutron capture on tellurium of terrestrial isotopic composition would produce excess Xe$^{129}$ and Xe$^{131}$ in the ratio Xe$^{129}$/Xe$^{131} = 0.63$. Since the anomalous xenon in the troilite occurs in the ratio Xe$^{129}$/Xe$^{131} = 5.9$, this origin of the Xe$^{131}$ would suggest the presence of $7.9 \times 10^{-12}$ cc STP radiogenic Xe$^{129}$ per gram of troilite or $8.8 \times 10^{-5}$ cc STP radiogenic Xe$^{129}$ per gram of iodine.

For the continuous synthesis model described by Kohman$^{24}$, Kuroda$^{25}$ has calculated the I$^{129}$/I$^{127}$ ratio, $\beta$, at the end of galactic nucleosynthesis to be $\beta = 3 \times 10^{-3}$. This corresponds to a maximum of 0.52 cc STP radiogenic Xe$^{129}$ per gram of iodine for meteorites which start to retain the gaseous Xe$^{129}$ decay product immediately after nucleosynthesis. Since the Great Namaqualand troilite contains $8.8 \times 10^{-5}$ cc STP radiogenic Xe$^{129}$ per gram of iodine, this nodule began to retain radiogenic Xe$^{129}$ about 216 million years after an initial I$^{129}$/I$^{127}$ ratio of $3 \times 10^{-3}$.

The above is probably a minimum I$^{129}$ - Xe$^{129}$ age for this sample since fast neutrons may produce a larger Xe$^{129}$/Xe$^{131}$ ratio than thermal neutrons.

27 M. G. Inghram and J. H. Reynolds, Phys. Rev. 78, 822 [1950].

From the presently available cross section data on tellurium$^{26}$, it appears that nonthermal neutrons will produce a maximum Xe$^{129}$/Xe$^{131} \approx 3$. Excesses of Xe$^{129}$ and Xe$^{131}$ have been found in tellurium ores$^{27, 28}$ in the ratio Xe$^{129}$/Xe$^{68S} = 1.5 - 3$. These anomalies have been attributed to neutron capture on tellurium$^{27}$ and to negative muon reactions$^{29}$ on Te$^{130}$, Te$^{130}(\mu_-, n)$Sb$^{129}(\beta^-)$Te$^{129}(\beta^-)$I$^{129}(\beta^-)$Xe$^{129}$. If the excess Xe$^{131}$ was produced in some reaction which produced Xe$^{129}$/Xe$^{131} \leq 3$, then the radiogenic Xe$^{129}$ in the troilite nodule of Great Namaqualand could amount to as little as $4.3 \times 10^{-12}$ cc STP per gm. In this case the I$^{129}$ - Xe$^{129}$ formation interval would be 231 million years.

Thus the I$^{129}$ - Xe$^{129}$ formation interval for the Great Namaqualand troilite appears to be in close agreement with the I$^{129}$ - Xe$^{129}$ age of the Sardis troilite$^1$, but appreciably longer than the I$^{129}$ - Xe$^{129}$ age of Canyon Diablo graphite$^3$. The presence of excess Xe$^{129}$ from neutron capture reactions on tellurium in the troilite phases of both Sardis and Great Namaqualand are consistent with the proposed synthesis of I$^{129}$ in the solar system$^{30}$ and Te$^{128}$ - Xe$^{129}$ dating of meteorites$^{31}$.

Acknowledgments

We are grateful to Professor Paul D. Proctor and to the Museum of the University of Missouri-Rolla for providing us the sample of Great Namaqualand troilite. This research was supported by a National Science Foundation Grant, NSF-GA-1462. One of us (E.C.A.) was supported by an NDEA Fellowship.

31 P. K. Kuroda, R. S. Clarke, and R. Ganapathy, J. Geophys. Res. 72, 1407 [1967].