The pre-atmospheric size of Martian meteorites

Conference or Workshop Item

How to cite:

For guidance on citations see FAQs.

© [not recorded]

Version: [not recorded]

Link(s) to article on publisher’s website:

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online’s data policy on reuse of materials please consult the policies page.
THE PRE–ATMOSPHERIC SIZE OF MARTIAN METEORITES. O. Eugster, H. Busemann, and S. Lorenzetti, Physikalisches Institut, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland (eugster@phim.unibe.ch)

According to model calculations the upper limit of the radius of fragments ejected from Mars by asteroidal or cometary impact is about 2m, corresponding to a mass of about 100 tons [1]. In the present work we determined the lower limit of the pre-atmospheric size of martian meteorites based on the neutron flux induced by the cosmic-ray (CR) interaction with meteoritic matter.

We measured the Kr isotopic composition in eight martian meteorites. In all of them we observe effects induced by secondary cosmic-ray (CR) produced neutrons. Concentrations of neutron induced $^{80}$Kr, $^{80}$Kr$_n$, are obtained from

$$^{80}\text{Kr}_n = ^{83}\text{Kr}_c \left( ^{80}\text{Kr}^{\text{Kr}}/^{83}\text{Kr}^{\text{Kr}} \right) - ^{80}\text{Kr}^{\text{Spallation}}.$$  \hspace{1cm} (1)

The index 'c' denotes cosmogenic Kr and 's' spallation Kr. For $(^{80}\text{Kr}^{\text{Kr}}/^{83}\text{Kr})$, we adopt 0.765 [2]. The results are given in Table 1.

<table>
<thead>
<tr>
<th>Meteorite</th>
<th>$^{80}\text{Kr}_n$ (10$^{-12}$ cm$^3$ STP/g), Br concentration [6,7] (ppm), and CRE age, T (Ma).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles</td>
<td>0.98 0.7 3.04</td>
</tr>
<tr>
<td>QUE 94201</td>
<td>0.27 0.36 2.51</td>
</tr>
<tr>
<td>Shergotty</td>
<td>0.44 0.94 2.81</td>
</tr>
<tr>
<td>Zagami</td>
<td>0.24 0.79 3.15</td>
</tr>
<tr>
<td>Nakhla</td>
<td>0.99 4.05 10.8</td>
</tr>
<tr>
<td>Chassigny</td>
<td>0.44 0.12 11.3</td>
</tr>
<tr>
<td>ALH 84001</td>
<td>0.43 – 14.7</td>
</tr>
<tr>
<td>Sayh al Uhaymir 005</td>
<td>0.18 0.28 1.2</td>
</tr>
</tbody>
</table>

The production rate of $^{80}\text{Kr}_n$ is calculated from

$$P(^{80}\text{Kr}_n) = ^{80}\text{Kr}_n / (Br \cdot T).$$  \hspace{1cm} (2)

The Br concentration and T are given in Table 1 and $P(^{80}\text{Kr}_n)$ in Table 2. Marti et al. [2] have shown that $^{80}\text{Kr}_n$ is produced by epithermal neutron capture of $^{79}\text{Br}$ in the energy range 30–300 eV. The neutron flux, $\phi_n$, is then obtained from

$$\phi_n = P(^{80}\text{Kr}_n)/\sigma_{79},$$  \hspace{1cm} (3)

where $P(^{80}\text{Kr}_n) = 2.33 \cdot 10^{-32} P(^{80}\text{Kr}_n)$ and has the dimension neutrons cm$^{-2}$s$^{-1}$. The resonance integral $\sigma_{79}$ is 110 · 10$^{-24}$ cm$^2$ [3]. Fig. 1 demonstrates the resulting neutron fluxes. They are shown in relation to the fluxes of > 5 MeV neutrons that were calculated based on cosmogenic $^{21}\text{Ne}$ [8].

Two scenarios are possible how the meteoritic material might have experienced the observed neutron fluxes: (a) during a pre–exposure to cosmic rays in the regolith before ejection from Mars, and (b) as a meteoroid during the transfer from Mars to Earth.

The neutron flux as a function of depth within the martian regolith has not been measured but Lingenfelter et al. [4] give these data for the lunar regolith. We show that scenario (a) can be excluded because the expected neutron fluxes in the meteoritic material would be an order of magnitude higher than observed. For scenario (b) we obtain a slowing down density, q, for epithermal neutrons of

$$q = \phi_n \cdot \zeta \Sigma_{\text{tot}},$$  \hspace{1cm} (4)

where $\zeta \Sigma_{\text{tot}} = 0.0354$ cm$^{-1}$ for chondrites [5]. As the relevant element abundances in chondrites and martian meteorites are similar, this value is used here and we obtain

$$q = 0.0716 P(^{80}\text{Kr}_n).$$  \hspace{1cm} (5)

Based on the calculations of Eberhardt et al. [5] minimum radii, $R_{\text{min}}$, are obtained:

$$R_{\text{min}} = R_0 + aq,$$  \hspace{1cm} (6)
where $R_o = 22$ cm and $a = 118$ cm$^3$s. Fig. 1 shows the minimum pre-atmospheric radii as calculated from the measured $q$ values. The lower limit of the resulting radii (Table 2) is in the range of 22–27 cm. Taking the density of the martian meteorites into account we estimate the minimum pre-atmospheric masses to have been in the range of 150–270 kg.

Fig. 1 Secondary neutron flux ratio for 30–300 eV neutrons (from $^{88}$Kr) to $>5$ MeV neutrons (from $^{21}$Ne) vs. flux of 30–300 eV neutrons in martian meteorites. LA, Los Angeles; C, Chassigny; Q, QUE 94201; S, Shergotty; Z, Zagami; N, Nakhla; SaU, Sayh al Uhaymir 005.

Fig. 2. Minimum pre-atmospheric radii of martian meteorites calculated from the measured slowing down densities $q$ for epithermal CR produced neutrons. For meteorite names see caption to Fig. 1.

Acknowledgement: This work was supported by the Swiss NSF.