BROMINE IN INTERPLANETARY DUST PARTICLES; Jörg Bohsung, Peter Arndt, Elmar K. Jessberger, Max-Planck-Institut für Kernphysik, PO-Box 103980, 69029 Heidelberg, Germany

During the passage through the atmosphere the chemical composition of interplanetary dust particles (IDPs) may be altered not only by devolatilization upon heating [1] but also by contaminating processes [2]. Given the possible cometary origin of some IDPs, the understanding of such processes is fundamental for the interpretation of IDP trace element data in general. Recently Rietmeijer [3] reported the first observation of Br nanocrystals associated with IDP W7029E5 that conjecturally are of stratospheric origin. To support this interpretation, Rietmeijer presents a linear relationship of Br concentrations of 11 IDPs with theoretical stratospheric residence times. We will criticise Rietmeijer's model but nevertheless demonstrate that with the given data the Br enrichments can be interpreted as being due to contamination. We present a contamination model that predicts a linear relation of the absolute numbers of Br atoms in a given IDP with its capture area and sticking coefficient. A stratospheric contamination would naturally explain the Br enrichments observed in many stratospheric IDPs [e.g. 2, 4–7] and, if unequivocally proven, would discourage from speculations about exotic cosmic scenarios [4,7].

RIETMEIJER'S MODEL: According to [3], Br enrichments due to stratospheric contaminations via surface adsorption would result in a linear correlation of mass normalised Br concentrations to mass normalised atmospheric residence time: $\mathbf{C_{Br}(t)/m \propto t/m}$ (Eq. 1). To proof this prediction, Rietmeijer shows the data of a set of 11 particles (Tab. 1) according to Eq. 1 in a log-log plot, using particle masses m from [5,7] and residence times t which were calculated using a new model [8,9] for the settling of non-spherical dust particles. In that plot the data points are correlated linearly (Fig. 1, upper line).

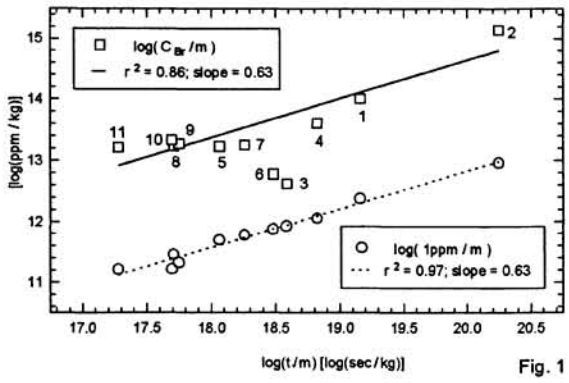


Fig. 1

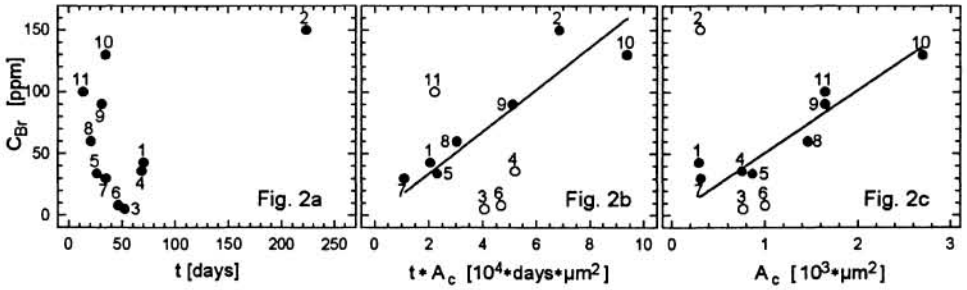
CRITICISMS: (1) The straight line does not proof Eq. 1, because it is incorrect to conclude a linear correlation of two variables if only their logarithms are linearly correlated. (2) The correlation itself is merely an artefact. This is obvious from the lower line of Fig. 1 where the same data are plotted assuming a constant (=1 ppm) Br concentration: the correlation is independent of the Br contents. Consequently, the real Br abundances are not responsible for the observed correlation but they rather tend to destroy it. The common cause for the same slopes of both correlation lines is the proportionality of log(1/m) and log(t/m). This is expected since in the Rietmeijer model the residence time t increases with decreasing particle mass m. The measured Br abundances then introduce a slight perturbation since the variation of $\log(C_{Br})$ is small compared to that of log(1/m). (3) The residence time model of Rietmeijer only is valid if the original preterrestrial size and shape of an IDP are known. But at least 2 out of 11 IDPs, W7066*A4 and W7029*A27, are associated with clusters that probably were produced from larger particles by disaggregation during collection [11], and there the model is not applicable.

NEW MODEL: We assume that (1) the original Br abundance of an IDP is low compared to a stratospheric contamination and that (2) the Br contamination rate is constant during the settling process. Then the absolute number of Br atoms $N_{Br}(t)$ should be proportional to the residence time t, to the capture area A_C of the particle and to a sticking coefficient s, which is a measure of the surface morphology and chemistry of a given dust grain: $\mathbf{N_{Br}(t) \propto t \cdot A_C \cdot s}$ (Eq. 2). A_C characterises the capture probability and s the probability that the particle holds the Br atom (even after cleaning procedures). As the capture area A_C we take the geometrical contour. There is, however, no good measure for the sticking coefficient s. Therefore we make the third assumption that as a first approximation s is proportional to the particle mass m. This is justified if the number of possible chemical reaction partners for Br increases with the particle mass which is supported by the observation that Br is absent from the surface but rather concentrated in the FeO-rich portion of the volume in one IDP [12]. With this it follows: $\mathbf{N_{Br}(t) \propto t \cdot A_C \cdot m}$ (Eq. 3). This contrasts to Eq. (1) which, by use of $C_{Br} \sim N_{Br}/m$ can be transformed to $\mathbf{N_{Br}(t) \propto t \cdot m}$ (Eq. 4) and thus does not take into account the capture probability A_C in addition to the sticking probability s represented by the particle mass m.

BROMINE IN INTERPLANETARY DUST PARTICLES; Bohsung et al.

Eq. (3) implicitly assumes short residence time t i.e. that the particle is not Br saturated (slow contamination model). If the contamination process is fast compared to typical residence times, then N_{Br} becomes independent of t (fast contamination model): $N_{Br}(sat) \propto A_c \cdot m$ (Eq. 5).

In Fig. 2 the three situations as expressed in Eq. 4 (Rietmeijer's model) and Eqs. 3 and 5 (our models) for the set of 11 IDPs used by [3] are depicted after dividing both sides by the mass, i.e. plotting C_{Br}[ppm] versus t[days] (Fig. 2a), versus $t*A_c$[days*μm^2] (Fig. 2b) and finally versus A_c[μm^2] (Fig. 2c). Capture areas A_C are estimated from geometry data [10]. In Fig. 2a the data points are not correlated whatsoever but scatter rather widely. This already indicates that the original assumption of Rietmeijer [3] is insufficient for any statement on the probability of stratospheric Br contamination processes.



This contrasts to our models depicted in Fig. 2b and Fig. 2c where almost all data points are linearly correlated. Unlike in Fig. 1, the slopes of the correlation lines now are physically significant: they characterise the increase of Br concentration with time and capture area (Fig. 2b) and capture area (Fig. 2c), respectively. A more detailed investigation of Figs. 2b and 2c reveals that in both cases the correlations mainly depend on the variation of the capture area A_C. If at all, the residence time t seem to play only a minor role, since the correlation of Fig. 2c is higher than that of Fig. 2b with only one particle (U2022G17) being far off the correlation line. Therefore we conclude that our simple fast contamination model can explain the observed bromine enrichments as caused by stratospheric contamination. If the latter is true, then broken cluster particles are no longer problematic: because of the short duration of contamination now one could conceive Br enrichments of the cluster fragments even after their collision with the sampling collector. In conclusion, with our simple model the Br enrichment data – at least for the available rather small set of IDPs – can be understood as due to stratospheric contamination processes, supporting the experimental observations by Rietmeijer [3] that stratospheric Br-salt nanocrystals are associated with IDP W7029E5.

Nr.	IDP Name	Mass [pg]	C_{Br} [ppm]	Times [days]	A_{c_2} [μm^2]
1	W7066*A4	424	43	70.8	292
2	U2022G17	110	150	223.7	307
3	W7013H17	1188	5	53.0	769
4	U2022C18	892	36	68.8	758
5	U2022G2	2000	34	26.8	870
6	U2022B2	1333	8	46.7	1004
7	W7029*A27	1666	30	35.1	314
8	W7013A11	3500	60	20.8	1464
9	U2001B6	4776	90	31.1	1647
10	U2022G1	6056	130	34.8	2700
11	U2015G1	6111	100	13.5	1647

Table 1: Particle masses and Br concentrations from [5,7], residence times from [3]. Capture areas A_C are calculated using particle dimensions and shapes from [10]. Numbers in the first row allow IDP identification in Figs. 1 and 2.

References: [1] Flynn, G., ICARUS 77, 287-310, 1989. [2] Jessberger, E. K., J. Bohsung, S. Chakaveh, and K. Traxel, Earth Planet. Sci. Lett., 112, 91-99, 1992. [3] Rietmeijer F. J. M., J. Geophys. Res., E4, 7409-7414, 1993. [4] Van der Stap, C. C. A. H., Academisch Proefschrift, University of Amsterdam, The Netherlands, 1986. [5] Sutton S. R., and G. J. Flynn, Proc. Lunar Planet. Sci. Conf., 18th, 607-614, 1988. [6] Wallenwein, R., Ch. Antz, E. K. Jessberger, A. Buttewitz, A. Knöchel, K. Traxel and M. Bavdaz, Lunar and Planet. Sci., XX, 1172-1173, 1989. [7] Flynn, G. J., and S. R. Sutton, Proc. Lunar Planet. Sci. Conf., 20th, 335-342, 1990. [8] Rietmeijer F. J. M., J. Volcanol. Geotherm. Res., 55, 69-83, 1993. [9] Wilson, L., and T. C. Huang, Earth Planet. Sci. Lett., 44, 311-324, 1979. [10] Flynn, G. J., and S. R. Sutton, Proc. Lunar Planet. Sci., 21, 541-547, 1991. [11] Cosmic Dust Courier Nr. 7, Code SN2, p. 13, NASA/Johnson Space Center, 1986. [12] Stephan, T., W. Klöck, E. K. Jessberger, and J. Zehnpfennig, Meteoritics, 27, 292, 1992.