

MODEL CALCULATIONS OF SOLAR WIND AND SEP NEON ISOTOPIC DISTRIBUTIONS IN LUNAR REGOLITH GRAINS. R. H. Becker, School of Physics and Astronomy, Univ. of Minnesota, Minneapolis, MN, 55455.

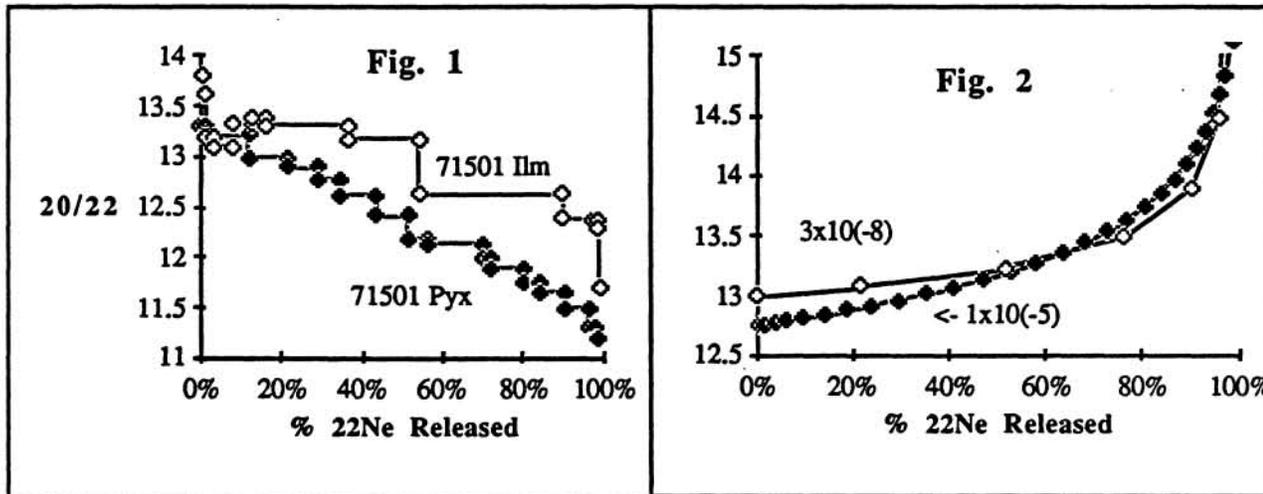
Analyses of trapped solar noble gases in lunar mineral grains have resulted in two differing interpretations of the data obtained (1-4). On one hand, the data have been explained as a superposition of recently implanted and essentially unfractionated (particularly in ilmenite grains) solar wind (SW) upon older generations of SW which have been fractionated and redistributed by diffusive loss (1,2). On the other hand, they have been explained in terms of a mixture of relatively unfractionated (isotopically) SW with a second noble gas component of solar origin implanted at somewhat higher energies than the SW itself and having different isotopic ratios, which has been termed SEP (3,4). These two interpretations rest on somewhat different data sets, and have therefore been difficult to reconcile. It has in fact been suggested that the data in (1,2) may be affected by diffusion during analysis itself (5). In an attempt to get some new insight on the problem, I decided to model mathematically the results that might be expected from the different interpretations. Because the analytical techniques used by the Zurich group (3,4) nominally yield depth profiles for the elemental and isotopic ratios of the gases in the mineral grains unaffected by laboratory diffusion, whereas those in (1,2) may not, the goal was to see whether combinations of implantation and diffusion profiles could be made to approximate release profiles given in (4). For the initial simulations, $^{20}\text{Ne}/^{22}\text{Ne}$ release profiles were chosen (Fig. 1), since relative diffusion rates for isotopes are better defined than for elements.

Concentration profiles were calculated using an equation for diffusion of shells in a sphere (radius = $70\ \mu$) of uniform diffusion coefficient (6). The component diffusing was assumed to be completely present at the start of diffusion. In lunar terms, this corresponds to a situation in which the duration of implantation is a negligible fraction of the diffusion time. The other extreme, in which diffusion occurs only during irradiation (as if driven by heating during implantation, for example), has not yet been calculated. Initial implantation profiles were chosen for ^{20}Ne and ^{22}Ne for both the SW and SEP components, and concentration profiles were calculated for a set of values of Dt/a^2 (D = diffusion coefficient, t = time, a = grain radius). Values of Dt/a^2 between 3×10^{-8} and 10^{-4} were used for ^{22}Ne , with those for ^{20}Ne being 1.04881 times larger (i.e., $(22/20)^{1/2}$). These correspond to losses for the SW component from about 40% to 99.5%, with significantly smaller losses for the SEP component. Several initial distributions were tried for both SW and SEP components. SW implantation profiles were placed between 0 and $300\ \text{\AA}$, either as a uniform concentration, a gaussian-shaped profile or a profile weighted towards the surface and tailing off with depth. SEP implantation profiles all decline in a linear way with depth, from the surface to either 2000, 10000, or 50000 \AA . One variant of the SW profile was tried in which ^{20}Ne was weighted slightly towards the surface relative to ^{22}Ne , to model the situation in which the lighter isotope is implanted with somewhat lower energy than the heavier (7). Initial $^{20}\text{Ne}/^{22}\text{Ne}$ ratios were assumed to be 13.7 and 11.3 for SW and SEP, respectively.

A sample of the results of the calculation are shown in Fig. 2, for two different values of Dt/a^2 for the same initial implantation profile. Results for SW are essentially independent of implantation profile, except that the curves for the case where ^{20}Ne was preferentially weighted towards the grain surface lie at somewhat lower $^{20}\text{Ne}/^{22}\text{Ne}$. Curves for SEP are roughly similar, although it requires longer times for a given shape to develop, and they lie at lower $^{20}\text{Ne}/^{22}\text{Ne}$, reflecting the lower initial isotopic ratio. Once such curves have been calculated for each value of Dt/a^2 , results for different values can be added together. This corresponds to multiple surface exposures separated by periods of burial. By choosing which profiles to add, one can simulate a variety of exposure histories. At present, variations of SEP to SW from one implantation event to another (simulating a secular change in the implantation ratio, for example) have not been incorporated, although the overall implantation ratio of SEP to SW can be

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changed. The case in which a grain is shielded from SW but not from SEP has also not been considered. (This effectively would require a different, shallower initial SEP profile for such exposure episodes.)



As the above indicates, a number of assumptions and simplifications are built into the model. As a result, a couple of very general observations are warranted. These observations are applicable to experiments in which the release process is non-diffusional (i.e., surface etching.) First, it appears that no combination of undiffused SW added to SW diffusion profiles such as those shown in Fig. 2 can yield the release patterns shown in Fig. 1. By implanting ^{20}Ne closer to the surface (1,7), it is possible to get diffused profiles with minima around 12.2 in $^{20}\text{Ne}/^{22}\text{Ne}$. Addition of undiffused SW would produce higher ratios at low release fractions. However, all the model curves tested have significant tails of increasing $^{20}\text{Ne}/^{22}\text{Ne}$ in the last 20% or so of release, not seen in Fig. 1. In order to avoid these tails of increasing $^{20}\text{Ne}/^{22}\text{Ne}$, it appears necessary to have an SEP component present.

Second, none of the combinations of undiffused SW plus SEP tested yielded curves like those in Fig. 1. If the implantation profile for the SEP extends to a micron or more, then one basically obtains a step-function in $^{20}\text{Ne}/^{22}\text{Ne}$ between the SW and SEP value. There is no evidence for the gradual change shown by pyroxene in Fig. 1, and $^{20}\text{Ne}/^{22}\text{Ne}$ for late release fractions is the SEP value, rather than intermediate values such as are seen in ilmenite. To avoid getting the pure SEP value, it is necessary to have the SEP implanted to depths only a few times that of the SW component, in which case one gets relatively low $^{20}\text{Ne}/^{22}\text{Ne}$ in the early release. To avoid the step-function in $^{20}\text{Ne}/^{22}\text{Ne}$, it appears that the presence of a diffused SW component is necessary. As of yet, it has not been possible to determine a ratio of SEP to SW in the initial implantation which will yield results approximating those in Fig. 1, although ratios below 0.1 and above 0.5 give the poorest results.

Since one of the peculiarities of the data in (4) is that noble gases released in early etching steps appear to have unfractionated isotopic ratios but fractionated element ratios, future simulations will be extended to include elemental ratios. The ability to mimic these additional observations should lend more confidence to the results of such simulations.

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