A PRELIMINARY ASSESSMENT OF CHONDRULE COOLING RATES IN PLANETESIMAL BOW SHOCKS, INCLUDING H_2 RECOMBINATION. M.A. Morris[1], S.J. Desch[1], and F.J. Ciesla[2]. [1]School of Earth and Space Exploration, Arizona State University. Email: melissa.a.morris@asu.edu. [2]Department of the Geophysical Sciences, University of Chicago.

Introduction: Chondrules represent one of the best probes of the physical conditions and processes acting in the solar nebula. Chondrule formation models are judged by their ability to match experimental constraints on chondrule formation, especially their thermal histories. The model most consistent with chondrule thermal histories appears to be passage through shock waves in the solar nebula, though the sources of shocks are not well constrained. Gravitational instabilities in the solar nebula can produce large-scale (1-D) shocks of the right speeds [1]. Bow shocks driven in advance of eccentric planetesimals are another promising mechanism, especially given the high probability of such events [2-4]. Planetesimals at 3 AU on eccentric orbits will drive shocks with speeds of 5-10 km s^{-1}, depending on their eccentricity. However, the radiation field in models [5-7] is calculated only in 1-D, assuming very large-scale shocks. Planetesimal bow shocks are parabolic and small in scale. Cooling rates in bow shocks have been estimated to be ~ 10^4 K hr^{-1} [4], which are too rapid to match chondrule thermal histories. Cooling rates can be reduced by factors of 2–10, though, by H_2 recombinations [6,7]. Investigations of chondrule heating in planetesimal bow shocks have not yet included 2-D radiative transfer or the energetics of H_2 recombination. Here we present a preliminary investigation to include these effects in bow shock models.

Results: We use the shock code of [6,7] to carry out our calculations of chondrule thermal histories in simulated bow shocks. Instead of a 1-D radiation field, we assume the chondrules of interest are surrounded by a cloud of chondrules at the same temperature, so that effectively the radiation field they see is $J = B(T_{\rm bkgrnd})\exp(-\tau) + B(T_{\rm ch})[1 - \exp(-\tau)]$, where τ is the frequency-averaged (Rosseland mean) optical depth from the center of the cloud of chondrules to its edge. The cloud is assumed to be ~ 2 times the radius of the planetesimal. Several simulations were run with shock speeds ranging from 8 - 10 km s^{-1}, gas density 10^{-9} g cm^{-3}, and chondrule densities ranging from 0.004 – 0.075 times the gas density. τ varied as the size of the cloud was varied. We found that H_2 dissociation/ recombination does reduce the cooling rates, but by small factors ≈ 2, near 1800 K.

Discussion: Our analysis makes clear that cooling rates of chondrules in planetesimal bow shocks may be buffered by H_2 recombination and reduced by factors of ≈ 2, at least at the centers of the shocked cloud of chondrules, but rates $< 10^2$ K hr^{-1}, befitting porphyritic chondrules, require much more optical depth ($\tau >> 1$) than standard parameters predict. However, a combination of large planetesimal, high chondrule concentrations, and high gas densities may yet result in such cooling rates, when detailed radiative transfer and line cooling by H_2O molecules are included in a fully 2-D model.

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