AN ISOTOPIC CRISIS FOR THE GIANT IMPACT ORIGIN OF THE MOON? H. J. Melosh, Lunar and Planetary Lab, University of Arizona, Tucson AZ 85721. Email: jmelosh@lpl.arizona.edu

Introduction: Over the past decade the impressive increase in precision of isotopic measurements, particularly for oxygen, have made it clear that, at current precision, the Earth and Moon are isotopically indistinguishable from one another at the level of five parts per million [1], despite their profound chemical differences. The current version of the giant impact theory of the Moon's origin, however, predicts that about 70% of the Moon's mass is inherited from the projectile, while only about 10% of the Earth's mass was contributed by this object [2]. Unless the isotopic compositions of the proto-Earth and projectile were nearly identical by some fortuitous coincidence, there should be detectable differences between the isotopic composition of the present Earth and Moon, as argued persuasively in [1].

Isotopic Equilibration in the disk? Pahlevan and Stevenson [1] recently argued that turbulent convection in an "atmosphere" of vapor common both to the orbiting disk and the proto-Earth could plausibly equilibrate the isotopic composition of the disk and Earth. However, it seems inevitable that the exchange of enough material to equilibrate isotopic compositions would inevitably also equilibrate angular momentum: It seems impossible to separate exchange of parcels of matter between the Earth and disk from a concurrent exchange of angular momentum. However, the angular momentum of the present Earth-Moon system is apparently too small to support an extended disk if all parts of it shared angular their momentum: The proto-Earth would rotate with a period of about 4 hours if all of the angular momentum of the Earth-Moon system were concentrated in it, while a comparable rotating sphere only begins shedding mass at its equator at a period of about 1.5 hour. Although the Earth-Moon system is estimated to have lost about 20% of its initial angular momentum to solar tides, the present angular momentum is believed to be close to its primordial value [2].

The Crisis: Without a plausible mechanism to strongly separate angular momentum transport from mass exchange, the Pahlevan and Stevenson mechanism [1] cannot explain the equilibration of isotopes between the Earth and Moon. So how do we account for the obvious isotopic similarity? We are not left with any highly plausible alternatives. Perhaps the Moon-forming impact was more central and the hot silicate gas was spun out to form the Moon after complete mixing with the proto-Earth, in a sort of return to the Darwin fission model (but with a much hotter initial Earth). For this to work, the angular momentum lost to solar tides must be much larger than previously thought possible. Perhaps the Q of a partly molten planet has been greatly underestimated. Or perhaps the SPH simulations of the Moon-forming impact do not correctly reflect the actual mix of materials achieving orbit: The SPH method is notorious for its underestimates of material mixing. A computation of the giant impact by other techniques than SPH is urgently needed.

In any case, the increasingly precise measurements of the isotopic ratios of elements composing the Earth and Moon have brought us to a new crisis in the still-unresolved problem of the Moon's origin. New, bold ideas will be required in the future.

References: [1] Pahlevan, K and Stevenson, D. J. 2007. *Earth and Planetary Science Letters* 262:438–449. [2] Canup, R. 2004. *Icarus* 168: 433-456.