ISOTOPIC SIGNATURES ASSOCIATED WITH QUANTUM TUNNELING OF ATOMIC OXYGEN ON COLD DUST GRAIN SURFACES. J. Lucas, B. U. Resendiz, and G. Dominguez, Department of Physics, California State University San Marcos (lucas035@cougars.csusm.edu)

Introduction: Decades of precise laboratory measurements of terrestrial samples, cometary dust, primitive meteorites and their sub-components, and the solar wind have established that the Sun and the planetary bodies (Earth, Mars, asteroids, comets, primitive meteorites) have significant differences in the relative abundances of isotopes of major elements such as hydrogen, carbon, nitrogen, and oxygen [1][2][3][4] . These differences, which arguably place the most stringent constraints on formation of the solar system's terrestrial bodies (e.g. the planets, comets, asteroids, etc.), are not well understood in large part because of our incomplete understanding of how physical processes affect the relative abundances of stable isotopes in astrophysical environments [5][6].

We evaluate how quantum mechanical tunneling (QMT) of oxygen isotopes on cold dust grain surfaces may change their relative abundances. While previous work has largely focused on understanding QMT of hydrogen isotopes, recent experimental work presenting evidence of significant QMT by oxygen atoms suggests that diffusion via QMT may also be important for other atoms heavier than hydrogen [7][8]. Although our focus here is on oxygen, we note that our general approach should also apply other elements that are “volatile" and therefore mobile in cold astrophysical environments including carbon and nitrogen.

At low temperatures (T<20 K) characteristic of molecular cloud cores, diffusion on dust grain surfaces via thermal hopping slows significantly and the prevailing mechanism for atomic diffusion becomes QMT. Motivated by experimental work presenting evidence of quantum tunneling of elements heavier than hydrogen and the possibility that this process may have isotopic signatures associated with it, we carried out simulations to determine the timescales associated with quantum tunneling of oxygen isotopes. In contrast with the standard treatments in the astrophysical literature, which treat quantum tunneling as a potential barrier transmission problem, we defined 1-D potential wells and solved the Schrödinger equation numerically to determine the energy eigenstates and eigenfunctions of atoms on these surfaces. This approach allowed us to calculate the tunneling timescales for isotopes of oxygen and hydrogen and associated instantaneous isotopic fractionation factors for a range of well-size and potential energy barriers. As a result of these studies, we find that conventional QMT calculations underestimate the rates of quantum tunneling by several orders of magnitude compared to the more physical procedure we describe here. These differences in QMT timescales result in modest to significant differences in the instantaneous isotopic fractionation factors for isotopes of hydrogen and oxygen. Regardless of the approach taken to compute fractionation factors associated with QMT of oxygen isotopes, we find that tunneling on cold surfaces may produce isotopic enrichment and depletion patterns that would be characterized as mass-independent.

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