Geochemical approach to the determintion of the ^{100}Mo double beta decay half-life

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Double beta decay (DBD) is a rare second order decay, which involves the transmutation of one element of atomic number Z to another of Z+2. This decay occurs when normal beta decay is energetically forbidden, and is associated with the release of two eletrons and either two neutrinos ($2\bar{\upsilon}$) or no neutrinos ($0\bar{\upsilon}$) depending on the neutrino mass. The two decay schemes ($2\bar{\upsilon}$ & $0\bar{\upsilon}$) have distinctly different decay half-lives, making double beta decay an excellent test for neutrino mass and lepton conservation.

In this work we look at the DBD of ^{100}Mo to ^{100}Ru, which has one of the highest decay energies compared to other DBD candidates. To date this ^{100}Mo DBD has been examined mainly through the use of direct counting, which suffers greatly from low count rates. Here we present the ongoing development of a geochemical method for the determination of its half-life, using geological time-scales for the accumulation of daughter species.

For our work, samples of molybdenites (MoS_2) were measured for Ru concentration and isotopic composition, and ages via Re-Os dating. Preliminary Ru concentration analysis resulted in concentration of natural Ru in Mt Mulgine and Osbourne molybdenites of 890 ppt and 255 ppt respectively. While Re-Os dating of the Mt Mulgine molybdenites via ICPMS indicates an age of 2807 ± 149 Ma, no meaningful date was obtained for Osbourne due to a possible disturbatance of the Re-Os systematics in this sample.

Calculations using the half-life values of (8.0 ± 0.7) x10^{18} yrs, average of all “positive” $2\nu\beta\beta$–decay results (Barabash, 2002), for the ^{100}Mo-^{100}Ru decay, and natural Ru concentration in the 2.8Ga-old MoS_2 estimated in this study indicates that the ^{100}Ru isotope should see significant shift (~12%) due to DBD products. This anomaly will be easily detectable with the current analysis technique, given the elimination of Mo isobaric interferences. We hope to report detailed Ru isotopic data from the Mt Mulgine MoS_2 during the conference, and an estimate of the DBD half-life.

References

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Self-shielding of CO in the Surface of the Solar Nebula

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Self-shielding of $^{12}C^{16}O$ and concomitant depletion of the rare isotopologues of CO (e.g., ^{13}CO, $C^{18}O$) are well known to occur at the edges of molecular clouds. Self-shielding occurs because the predissociation absorption lines in the more abundant $^{12}C^{16}O$ become saturated at shorter pathlengths than for the CO isotopologues. The absorption lines of the isotopologues do not, in general, overlap those of $^{12}C^{16}O$, resulting in a higher photodissociation rate coefficient for the former. Recently Clayton (2002) suggested that the same process operated in the inner solar nebula (i.e., near the X-point in the X-wind model) and led to an ^{17,18}O enrichment in primitive solar system material (other than CAI’s). Here we focus on CO dissociation in the cooler, surface layers of the nebula.

We utilize the disk model of Aikawa and Herbst (1999) for a flared disk with an isothermal vertical temperature profile. We also assume a dust grain population dominated by 3 micron particles and with a column abundance proportional to the column abundance of H_2. The central star has a direct view of the surface of the disk, and FUV (far-UV) radiation can photodissociate CO in this region. To characterize mutual and self-shielding effects by H_2 and CO at CO photodissociation wavelengths, we employ the shielding functions of van Dishoeck and Black (1988) for the CO and $C^{18}O$ isotopologues. We assume a protosolar FUV enhancement ~ 10^4 times the modern solar values at ~ 100 nm, consistent with the highest UV enhancements seen in T-Tauri stars.

In order to quantify total CO dissociation, vertical transport timescales must be considered. We assume an α-disk with α~0.01, which corresponds to turbulent velocities ~ 0.01 – 0.1 km s^{-1} and transport timescales ~ 10^2 to 10^4 years, depending on radial location in the disk. The source of the turbulence is presumably MHD instabilities (e.g., Balbus-Hawley). For a vertical transport timescale ~ 10^3 years, oxygen from dissociated CO has δ^{18}O ~ +1000 ‰. Integrating all dissociated CO below this height in the disk yields ~ 3 M_{earth} of oxygen at ~ 1000 ‰, which is enough to cause a 50 ‰ shift in all of the oxygen in a 0.02 M_{solar} solar nebula.

The excess ^{17,18}O liberated during CO photolysis is converted to H_2O via the reaction O + H + H on grains, as suggested by Yurimoto and Kuramoto (2002). The timescales for H_2O formation will be presented.

References

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