Evolution of the Solar Nebula. IX. Gradients in the Spatial Heterogeneity of the Short-Lived Radioisotopes ^{60}Fe and ^{26}Al and the Stable Oxygen Isotopes

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Short-lived radioisotopes (SLRI) such as ^{60}Fe and ^{26}Al were likely injected into the solar nebula in a spatially and temporally heterogeneous manner. Marginally gravitationally unstable (MGU) disks, of the type required to form gas giant planets, are capable of rapid homogenization of isotopic heterogeneity as well as of rapid radial transport of dust grains and gases throughout a protoplanetary disk. Two different types of new models of a MGU disk in orbit around a solar-mass protostar are presented. The first set has variations in the number of terms in the spherical harmonic solution for the gravitational potential, effectively studying the effect of varying the spatial resolution of the gravitational torques responsible for MGU disk evolution. The second set explores the effects of varying the initial minimum value of the Toomre Q stability parameter, from values of 1.4 to 2.5, i.e., toward increasingly less unstable disks. The new models show that the basic results are largely independent of both sets of variations. MGU disk models robustly result in rapid mixing of initially highly heterogeneous distributions of SLRIs to levels of $\sim$ 10% in both the inner ($<$ 5 AU) and outer ($>$ 10 AU) disk regions, and to even lower levels ($\sim$ 2%) in intermediate regions, where gravitational torques are most effective at mixing. These gradients should have cosmochemical implications for the distribution of SLRIs and stable oxygen isotopes contained in planetesimals (e.g., comets) formed in the giant planet region ($\sim$ 5 to $\sim$ 10 AU) compared to those formed elsewhere.

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