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Beating the miscibility barrier between magnesium and iron group metals (Fe, Ni, Co) by high-pressure alloying

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It is now generally recognized that all metals and compounds show some solubility in the solid or liquid state, but the extend of solid solubility is different in different cases. In particular, Fe and Mg are almost immiscible at ambient pressure. The maximum solid solubility of Fe in Mg is 0.00041 at. % Fe, and the Mg concentration at the eutectic point is estimated to be less than 0.008 at.%. Below 1273 K the solubility of Mg in Fe is below the detection limit, while the maximum solid solubility of Mg in δ-Fe is approximately 0.25 at.% Mg at the monotectic temperature. There is clear evidence that magnesium and iron do not mix in the liquid state at ambient pressure. Though two close chemical analogues of iron, namely nickel and cobalt, form intermetallic compounds with magnesium, solubility of Mg in these metals is also negligibly low. Different paths are exploited nowadays to synthesise alloys between immiscible elements, e.g. mechanical alloying by means of ball milling or thin film alloying using deposition techniques. Here we exploit an alternative path for overcoming miscibility barrier. The low solubility of Mg in Fe is in complete agreement with well-known Hume-Rothery rule for metallic alloys, which states that the formation of disordered metallic alloys is very unlikely if atomic sizes of alloy constituents differ by more than 15%. However, compressibility of Mg is much higher than that of Fe, and therefore the difference in atomic sizes between these two elements decreases dramatically with pressure. Based on the predictions of *ab initio* theoretical calculations, we demonstrate in series of experiments in a multianvil apparatus and in electrically- and laser-heated diamond anvil cells, that high pressure promotes solubility of magnesium in iron and at megabar pressure range more than 10 at% of Mg can dissolve in

Fe, and then quenched to ambient conditions. Up to 4 at% of Mg could be dissolving in Ni or Co at 20 GPa and 2200 K. At pressures above 95 to 100 GPa, molten iron reacts with periclase MgO forming an iron-magnesium alloy and iron oxide. In particular, our observations suggest that magnesium can be an important light element in Earth's outer core.