OXYGEN ISOTOPE RATIOS OF NATURAL AND SYNTHETIC CHONDRULES: EVIDENCE FOR IN SITU REDUCTION BY CARBON. R. D. Ash[1,2,3], H. C. Connolly Jr.[4], C. M. O'D. Alexander[3], G. J. MacPherson[2] and D. Rumble III[1], [1]Geophysical Laboratory, Carnegie Institution, 5251 Broad Branch Road NW, Washington DC 20015, [2]Department of Mineral Sciences, MRC NHB-119, Smithsonian Institution, Washington DC 20560, [3]Department of Terrestrial Magnetism, Carnegie Institution, 5241 Broad Branch Road NW, Washington DC 20015, [4]CalTech, MC 100-23, Pasadena CA 91125 (ash@gl.ciw.edu).

Introduction: Experiments show that the characteristics of natural Type IA chondrules (both silicate and metal chemistry) are reproduced by the incorporation of a reduced carbon phase into the starting materials [1]. During heating the C is oxidised and lost as CO or CO_2, scavenging oxygen from the silicates thereby producing metallic Fe [1]. Fractionation factors indicate that the production of CO/CO_2 by olivine reduction should result in a mass dependent enrichment of the residue (i.e. chondrule) in the light O isotopes [2].

Herein we present O isotopic analyses of synthetic reduced chondrules to further test this C reduction model for Type IA chondrule formation. These data are then compared with the observations of a natural Type IA chondrule from Tieschitz.

Experimental: Four experimental charges were prepared; two with Type IA and two with Type IIA analogue compositions; 5 wt% graphite was added to one charge of each composition. These were then flash melted under identical conditions, at 1725°C and an fO_2 of -1.5 log units below IW maintained by a $CO\text{-}CO_2$ gas mixture. The resultant charges were petrologically characterised and analysed for O isotopes using the Carnegie Institution UV laser fluorination technique [3, 4]

Results: Oxygen isotopic fractionations were measured between both experimental pairs. Type IA and Type IIA analogue charges without graphite gave $\delta^{18}O$ values of +6.50‰ and +7.48‰, the corresponding charges with C gave $\delta^{18}O$ values of +5.62‰ and +6.32 respectively. As predicted, the presence of reduced carbon in the synthetic charge precursors leads to residues with lighter oxygen isotopic compositions, by 0.88‰ and 1.16‰.

Discussion: Chemically reduced chondrules have been used to infer the O fugacity and, hence, the dust/gas ratio of the solar nebula in which they are assumed to have formed [5,6]. However the analyses herein indicate that the mineral chemistry of chondrules may be profoundly affected by cosmochemically reasonable amounts of reduced, probably organic, C in natural chondrule precursors.

Comparison with a Natural Reduced Chondrule: Oxygen isotopic analyses of 25 ferromagnesian chondrules from Tieschitz show that 17 of them lie on a slope 1 line [7], which is indistinguishable from the Equilibrated Chondrite Line (ECL - [2]). These are interpreted as pristine isotopic compositions produced by the mixing of two components. A further seven, altered, chondrules lie toward more ^{18}O-rich compositions—to the right of this line on a three isotope plot; possibly due to parent body interactions between the chondrules and a fluid phase. One chondrule, however, lay toward lighter compositions, i.e. to the left of the ECL. This chondrule is a highly reduced Type IA chondrule, $Fo_{99.2\text{-}99.4}$ with metal containing dissolved Si and Cr. Assuming the initial O isotope composition of this chondrule precursor also lay on the ECL, we calculate a fractionation of 1.3‰ accompanied the reduction—close to that observed in the synthetic analogues.

Thus far this is the only well characterized OC chondrule with Fo>99 for which oxygen isotope ratios have been determined. One chondrule, from Bjurböle, has shown similar unusually light O but was not petrographically characterized [2]. The deviation from the ECL of this Bjurböle chondrule is the same as that of the Tieschitz chondrule. The lack of O isotope analyses of such chondrules may be due to their smaller size compared with "normal" chondrules [8], making isotopic analysis difficult. Alternatively it may reflect the paucity of these highly reduced chondrules.

Conclusions: We have shown that the incorporation of reduced C in synthetic chondrule analogue precursors leads to lighter O isotopes in the resultant chondrule.

The only O isotopic analysis of a known, highly reduced, UOC chondrule shows that it too has a uniquely light O isotopic composition. This observation demonstrates the importance of C in the formation of reduced chondrules.

References: [1] Connolly et al. (1994) *Nature, 371*, 136. [2] Clayton et al. (1991) *GCA, 55*, 2317. [3] Rumble et al. (1997) *GCA, 61*, 4229–4234. [4] Rumble et al. (1997) *M.A.P.S., 32*, A111. [5] Johnson (1986) *GCA, 50*, 1497. [6] Grossman (1988) in *Meteorites and the Early Solar System* (Kerridge & Matthews, eds.), p. 680. [7] Ash et al. (1998) *LPS XXIX*. [8] Jones and Scott (1988) *LPSC XIX*, 565.