The I-Xe record of metamorphism in CO3 chondrites. O. V. Pravdivtseva[1], A. P. Meshik[1], C. M. Hohenberg[1], and A. N. Krot[2], McDonnell Center for the Space Sciences and Department of Physics, Washington University, St. Louis, MO 63130, USA, (olga@wuphys.wustl.edu). [2]Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i at Manoa, Honolulu, HI 96822, USA.

Introduction: McSween presented the first strong case that CO3 chondrites represent a metamorphic sequence [1]. It was demonstrated later that the matrix of CO3 chondrites changes markedly during metamorphism. With increasing petrologic type, the range of olivine composition decreases [2] as well as the mean fayalite content of matrix olivine [3]. Abundances of presolar grains also decrease systematically with increasing petrologic type [4, 5], while abundance of secondary nepheline in chondrules and CAIs increases.

Magnetite is one of the first alteration products formed in carbonaceous chondrites during aqueous alteration. Although CO3 chondrites mainly experienced changes induced by heating on the meteorite parent body over a long timescale, presence of phyllosilicates indicates that water must have played an important role in the alteration history of matrices of some CO3 chondrites. Thus magnetites in CO3 chondrites could provide a timeline for the metamorphic changes on their parent body.

Results: Here we present I-Xe data for 11 magnetite-rich samples from CO3 meteorites of different petrologic type (Table). Magnetites were chemically separated following the LiCl procedure developed by Lewis and Anders [6]. LiCl could potentially contaminate magnetite with iodine and after irradiation produce non-correlated ^{128}Xe and perhaps spurious I-Xe ages. To evaluate this possibility, in our previous work we separated magnetites from two aliquots of Orgueil using the LiCl procedure, one before and another after irradiation. Only the before procedure would affect the I-Xe age. Both samples yielded I-Xe ages that agree within experimental uncertainties [7], confirming that chemical separation could not compromise I-Xe system.

Each CO3 meteorite studied was finely ground and stirred with a saturated LiCl solution for 8 days at 60°C to remove possible silicate-magnetite intergrowth. After further separation in NaOH and washing [8], the samples were dried and weighted, small amounts of resulting separates were saved for the later study of the magnetites morphologies. The purity of resulting magnetite was confirmed for Lancé by x-ray diffraction analysis. For the Orgueil CI chondrite this chemical separation procedure previously yielded magnetic fractions that were at least 90% pure [6]. The abundances of magnetites in this set of samples differ by more than order of magnitude (Table) and do not correlate with meteorites petrologic type.

All samples had masses of less than 1 gram before the chemical separation. Thus, if magnetites were distributed heterogeneously in the matrices, it would be difficult to obtain representative magnetite abundances.

The magnetite samples were sealed under vacuum in separate fused quartz ampoules and irradiated with thermal neutrons in the package designated SLC-16 at the Missouri University Research Reactor along with Shallowater, the usual reference standard and irradiation monitor. Xenon isotopic compositions were measured in 9 samples.

I-Xe system in bulk samples of Felix (3.3), Ornans (3.4), Lance (3.5) and Warrenton (3.7) have been previously studied [9]. Relative I-Xe ages in these meteorites correlated with their metamorphic sequence with most metamorphosed Warrenton being “undatable owing to homogenization of radiogenic and trapped Xe” [9]. I-Xe isochrons were well defined and formed by temperature points starting from 1100 ºC, indicating one iodine host phase [9].

If magnetite were the major iodine carrier phase in previous studies of bulk meteorites, chemical separation would result in higher observed iodine concentrations. But this is not the case. Iodine concentrations in pure magnetites of Felix, Ornans, Lancé and Warrenton are ~ 4 – 8 times smaller than in bulk samples, indicating the presence of at least two iodine-host phases in these CO3 chondrites. Indeed, when results are presented as three-isotope plots ^{128}Xe/^{132}Xe versus ^{129}Xe/^{132}Xe, three meteorites Colony, Lancé and Y-82094 yield double isochrons, where the low-temperature correlation lines indicate later closures of the I-Xe system, than the lines formed by the high-temperature extraction steps. The low-temperature iodine host phase most probably is magnetite. Previous studies [6], as well as our three independent measurements of Orgueil magnetite (from different irradiations and measured few years apart) all produce isochrons starting from 1100-1200 ºC [7, 10]. The high-temperature iodine host phase is most likely pyroxene. ALHA 77307 (3.0) is known to contain enstatite grains that are probably primary [11]. If so, pyroxene is a major iodine-host phase, and is responsible for the isochrons in the bulk samples of Felix, Ornans and Lancé. Small addition of this phase in Lance magnetite separate, that is at least 90% iron oxide, could be responsible for the high-temperature isochron in this sample.

Iodine concentrations (Table, column 5) do not correlate with petrographic type of the CO3 meteorites studied, while the radiogenic ^{129}Xe content seems to decrease with increasing petrographic type.

I-Xe ages are shown in column 8 of the Table. Three meteorites Y-81020, Kainsaz and Y-790992 had all their ^{129*}Xe released in only one experimental point within 3σ of the ordinary chondrites (OC) value. Experimental points for the Warrenton magnetite all cluster within 1σ of OC point. I-Xe ages for bulk Felix, Ornans and Lancé are shown in column 7 relative to the Shallowater. Negative I-Xe age values indicate I-Xe closure after Shallowater (4563.2 ± 0.6 Ma [12]). Two magnetites, Felix and Ornans, yielded single correlation lines, although Felix I-Xe isochron is defined with somewhat lesser precision. Both I-Xe ages agree within experimental uncertainties with the previous I-Xe age data for the bulk samples [9].

Colony, Lance, and Y-82094 high-temperature isochrons are in good agreement with I-Xe ages for the bulk samples as well as with Felix and Ornans data reported here. Low-temperature correlation lines indicate later closure for the I-Xe system in less refractory magnetite phase in Colony, Lance and Y-82094, that seems to correlate with their petrographic type.

The I-Xe system in CO3 meteorites reflects a complex metamorphic history. At least two iodine-host phases are present in these meteorites. The refractory phase, most probably pyroxene, closed about 2 Ma later than Shallowater. The I-Xe system in low-temperature magnetite closed 12 Ma after Shallowater in 3.0 Colony, and ~30 Ma after Shallowater in 3.5 Lance and Y-82094.

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CO3 meteorite, sample	type	Starting weight, mg	Separated magnetite %	Iodine >800 °C ppb	^{129*}Xe ×10^{-12} cm^3 STP/g	I-Xe age Ma [9]	I-Xe age, Ma	
							High T	Low T
Y-81020,101	3.0	349	0.34	0.3	1.38		—	—
Colony	3.0	706	1.40	7.3	18.10		-6.1 ± 3.1	-12.3 ± 2.9
Kainsaz	3.2	691	0.98	28	7.34		—	—
Y-82050,115	3.2	384	0.10	*to be measured*				
Felix	3.3	500	0.97	6.8	15.9	1.2 ± 2.1	-2.0 ± 1.5	
Ornans	3.4	556	0.40	14	47.1	-1.0 ± 0.7	-1.3 ± 0.5	
Y-790992,80	3.5	369	0.12	294	11.4		—	—
Lancé	3.5	531	0.14	10	7.07	-4.0 ± 1.9	-6.7 ± 6.0	~ -28
Y-82094,110	3.5	446	0.82	21	1.10		-2.2 ± 3.6	~ -30
ALHA77003,117	3.6	445	0.91	*to be measured*				
Warrenton	3.7	320	1.76	9.3	4.56	—	—	—