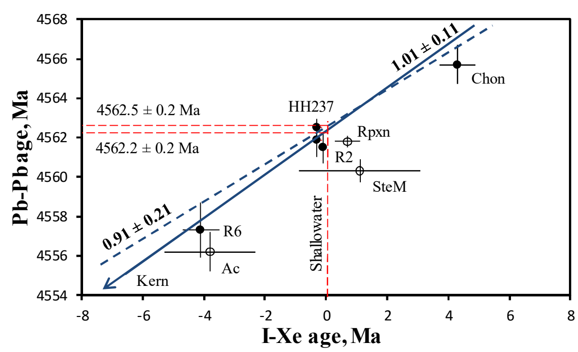
RE-EVALUATION OF THE ABSOLUTE CLOSURE AGE OF THE I-Xe STANDARD SHALLOWATER: IMPLICATIONS FOR THE ^{129}I HALF-LIFE VALUE. O. Pravdivtseva, A. Meshik and C. M. Hohenberg, Laboratory for Space Sciences and Physics Department, Washington University, CB1105, One Brookings Drive, Saint Louis, MO 63130 (olga@physics.wustl.edu).

Introduction: Short-lived chronometers allow us to decipher the early solar system history with a high degree of precision. Yet, they all provide relative ages and anchoring them to an absolute time scale presents a challenge. Ideally, to normalize the I-Xe chronometer to an absolute time scale, such as that provided by Pb-Pb, the I-Xe and Pb-Pb ages would be measured in the same mineral with the implicit assumption that both chronometers closed at the same time. However, minerals rich in iodine (hence ^{129*}Xe) usually have concentrations of uranium too low for high precision Pb-Pb dating, and *vice versa.* Therefore, finding suitable material is elusive and, even when we do, "pure" mineral separates often contain grains with differing I/U ratios and differing susceptibility to partial resetting by secondary processes and shock. Very few meteoritic materials fit the requirement for both good Pb-Pb and good I-Xe ages. The absolute age of Shallowater aubrite, the I-Xe standard, has never been measured directly due to its low U content. It is instead derived from the observed correlation between I-Xe and Pb-Pb ages in a number of different samples [1]. This approach is more reliable and allows for fine tuning of the absolute I-Xe age normalization when the new data become available. Here we re-evaluate the effective absolute I-Xe closure age of Shallowater with the addition of the new I-Xe data for Hammadah al Hamra (HH) 237 chondrule #1 [2] and Pb-Pb ages adjusted for an updated ^{238}U/^{235}U ratio of 137.794 and meteorite specific U-isotope ratios [3, 4, 5, 6, 7].

The closure age of Shallowater aubrite: According to the proposed single-stage highly energetic event formation scenario for CB chondrules [8], HH 237 skeletal olivine chondrule #1 represents melt fraction of the impact-generated plume. The presence of both U and I, and the likely simultaneous closure of both systems suggests HH 237 may provide suitable material and additional data for I-Xe age normalization. Release profiles and diffusion properties of radiogenic ^{129*}Xe and ^{128*}Xe extracted from this chondrule by step-wise pyrolysis, indicate presence of two iodine host phases with distinct activation energies of 73 and 120 kcal/mol. In spite of the activation energy differences, the I-Xe isotope systematics of these two phases closed simultaneously at 0.29 ± 0.16 Ma after Shallowater, suggesting rapid heating and cooling (possibly quenching) of the CB chondrules, and it was not affected by secondary processing. The release profiles of U-fission Xe and I-derived Xe correlate in the high temperature host phase supporting simultaneous closure of I-Xe and Pb-Pb systems. Because of the scarcity of interchondrule matrix material in CBs, the Pb-Pb age of silicates from the HH 237 chondrules can be represented by the 4561.9 ± 0.9 age of HH 237 silicates [8]. In addition, a U-corrected weighted average Pb-Pb age of 4562.49 ± 0.21 Ma for three magnesian skeletal Gujba (CB_a) chondrules has been reported [9]. For the absolute age computation (Figure 1 and Table 1) we include both values for HH 237 chondrule #1.

The Pb-Pb ages are corrected using latest U-isotope ratios for the Earth and solar system of 137.794 ± 0.027 and the meteorite specific U-isotope ratios for Richardton (137.711 ± 0.008) and Acapulco (137.796 ± 0.013). An average of two Allende bulk U-isotope ratios [5,7] of 137.78 ± 0.027 was applied to the Pb-Pb ages of the earliest chondrules and the value of 137.794 ± 0.014 for Gujba [5] used here as a proxy for HH 237 U-isotope ratio value.

Figure 1.



Assuming concordant evolution of I-Xe and Pb-Pb systems in the samples used for absolute age normalization, the slope of the Pb-Pb – I-Xe correlation line should be 1.00, if all half-lives are correct. Corrections for U-isotopic ratios brings the slope of the free fit Pb-Pb – I-Xe correlation line from the previous value of 0.96 ± 0.11 [1] to 0.98 ± 0.11. The addition of the HH237 chondrule #1 data (Table 1) brings the slope to 1.01 ± 0.11 (Fig.1), supporting simultaneous closure of the I-Xe and Pb-Pb systems in HH 237 chondrule #1 and valuable new data. Derived from this correlation the absolute age of Shallowater is 4562.2 ± 0.2 Ma, 0.1 Ma younger than the previous value [1]. There seems to be stronger correlation (higher R value) for the chondrule data within the available data set. The absolute age of Shallowater, derived from a correlation line that is based only on the chondrule data (Fig.1, solid symbols), is 4562.5 ± 0.2 Ma, although the slope of the line is 0.91 ± 0.21. We suggest a median value of 4562.4 ± 0.2 Ma as the best current estimate of the absolute age of Shallowater. This value could be further refined when new suitable data becomes available.

Implications for the ^{129}I half-life: The slopes of I-Xe – Pb-Pb correlation lines range from 1.01 ± 0.11 for the whole set of data points to 0.91 ± 0.21 for chondrules only. These slopes are dependent upon the half-life assumed for ^{129}I. The widely used value of 17 Ma is obtained as an *unweighted* average of all available half-life data [16, 17, 18, 19], since the most precisely quoted results of 15.6 ± 0.06 Ma [17] and 15.7 ± 0.06 Ma [18] Ma for the ^{129}I half-life contain insufficient experimental detail to be properly evaluated [20]. All I-Xe data used here and in the previous estimations of the absolute age of Shallowater [1] have been calculated using the 15.7 ± 0.8 Ma value, an average of two most precise measurements. In order to bring the slope of 0.91 ± 0.21 for the chondrules I-Xe and Pb-Pb ages correlation to about 1.00, the half-life of ^{129}I should be even lower, about 14.6 Ma. However, given the uncertainties, we can only propose that the half-life is less than the previously used value of 17 Ma. Although we cannot set the low limit for the half-life of ^{129}I based on these observations, since the slopes of I-Xe – Pb-Pb correlation lines are ≤ 1, the half-life of ^{129}I most probably is ≤ 15.7 Ma. This value is in a good agreement with half-life of ^{129}I 16.1 ± 0.7 Ma listed in Table de Radionucléides (BNM-LNHB/CEA, 2004) and based on the same data [16, 17, 18, 19] but calculated now as the *weighted* average. Since the ^{129}I half-life only affects the relative I-Xe ages, the few Ma relative to Shallowater, the absolute I-Xe ages are almost immune to this uncertainty in the ^{129}I half-life. A 10% difference in relative ages, consistent with using 17 Ma versus 15.7 Ma half-life value for calculations, will correspond to 0.004% difference in the absolute I-Xe ages for these samples.

Supported by NASA grant #NNX14A124G.

References: [1] Gilmour J. D. et al. (2009) *Meteoritics & Planet. Sci., 44,* 573–579. [2] Pravdivtseva O. et al. (2015) [3] Brennecka G. A. et al. (2010) *Science, 327,* 449–451. [4] Bouvier A. et al. (2011) *Geochim. et Cosmochim. Acta, 75,* 5310–5323. [5] Connelly J. N. et al. (2012) *Science, 338,* 651–655. [6] Brennecka G. A. and Wadhwa M. (2012) *Proc. Natl. Acad. Sci., 109,* 9299–9303. [7] Goldmann A. et al. (2015) *Geochim. et Cosmochim. Acta*, *148,* 145–158. [8] Krot A. N. et al. (2005) [9] Bollard J. et al. (2015) *Meteoritics & Planet. Sci., 50,* 1197–1216. [10] Swindle T. D. et al. (1991a) *Geochim. et Cosmochim. Acta*, *55,* 861–880. [11] Swindle T. D. et al. (1991b) *Geochim. et Cosmochim. Acta*, *55,* 3723–3734. [12] Pravdivtseva O. et al. (1998) *Meteoritics & Planet. Sci., 33,* A126–A127. [13] Gilmour J. D. et al. (2006) *Meteoritics & Planet. Sci.,41,* 19–31. [14] Brazzle R. H. et al. (1999) *Geochim. et Cosmochim. Acta*, *63,* 739–760. [15] Göpel C. et al. (1994) *Earth and Planet. Sci. Lett.*, *121,* 153–171. [16] Katcoff S. et al. (1951) *Phys.Rev., 82,* 688. [17] Russel H. T. (1957) Report ORNL–2293, 1–5. [18] Emery J. F. et al. (1972) *Nuclear Sci. and Engin., 48,* 319–323. [19] Kuhry J. G. and Bontems G. (1973) *Radiochem. and Radioanal. Lett.*, **15**, 29. [20] Holden N. E. (1990) *Pure and Appl. Chem.*, *62,* 941–958.

Table 1.

	I-Xe age, Ma (Shallowater ≡ 0)		**U-ratio corrected Pb-Pb age, Ma**	
Earliest chondrules	Chainpur, LL 3.4 [10] Semarkona, LL 3.0 [11]	4.3 ± 0.6	Allende, CV3	4565.6 ± 1.0
Richardton, H4	pyroxene [12] chondrule #2 [13] chondrule #6 [13]	1.1 ± 2.0 –0.1 ± 0.1 –4.1 ± 0.6	pyroxene chondrule #2 [13] chondrule #6 [13]	4560.3 ± 0.6 4561.5 ± 0.8 4557.3 ± 1.4
Acapulco	feldspar [14]	–3.8 ± 1.5	phosphate [15]	4556.2 ± 1.0
Ste Marguerite, H4	feldspar [14]	0.7 ± 0.4	phosphate [15]	4561.8 ± 0.3
Kernouve, H6	phosphate [14]	–43 ± 6	phosphate [15]	4521.6 ± 0.7
HH 237, CB	chondrule #1 [2]	–0.29 ± 0.16	HH 237 silicates [8] Gujba chondrules [9]	4561.9 ± 0.9 4562.5 ± 0.2