EXPOSURE AGES OF UREILITES: RADIONUCLIDES AND NOBLE GASES. J. Park[1,2], G.F. Herzog[1], M. K. Haba[3], K. Nagao[3]. [1]Dept Chem. & Chem. Biol., Rutgers Univ., Piscataway, NJ 08854, (jp975@rci.rutgers.edu), [2]Lunar & Planet. Inst., Houston, TX 77058, [3]Geochemical Research Center, The University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan.

Introduction: Cosmic-Ray Exposure (CRE) ages for about 20 ureilites are all younger than 50 Ma [1] (Figure 1), and generally comparable to those of chondrites, but much younger than the radiometric ages [2,3]. As for most meteorites, significant cosmic-ray exposure took place long after parent body accretion ended. Published, low activities of cosmogenic radionuclides for many ureilites suggest unusually small meteoroids (30 cm or less in radius, [4]). In an effort to improve the statistics of the CRE age distribution, test the generality of the conclusion concerning small meteoroids, and examine pairing relations, we present here the noble gas concentrations and the ^{26}Al and ^{36}Cl activities of samples from 13 Antarctic ureilites.

Experimental Methods: _Radionuclides:_ Samples with masses of ~50 mg were ground and then dissolved in concentrated HF and dilute HNO_3 after the addition of ~5-10 mg of Be, Al, and Cl, and Ca carriers. The samples were heated in Parr Bombs for 4-5 days at ~115 °C. Al, Be, Cl and Ca were chemically separated from the resulting solutions and purified for accelerator mass spectrometry at Purdue University as BeO, Al_2O_3, AgCl, or CaF_2.

Elemental analyses: Aliquots of the ground material (~10 mg) were dissolved for the elemental analysis by ICP-OES at Rutgers University. About half the analyses are complete at this time.

Noble gases: Fifteen sets of ureilite samples (~30-50 mg) were analyzed at the University of Tokyo using a noble gas mass spectrometer (modified-VG5400/MS-III). After preheating the samples at 150°C overnight to remove adsorbed atmospheric contamination, noble gases were extracted by heating at 1800°C for 30 minutes. Noble gas data were corrected for blanks, mass discrimination factors and sensitivity.

Results & discussion: Results are shown in Table 1. They agree well for GRA98032 and to within 20% for GRA 95205. The data confirm the pairing of the three ALH 82xxx meteorites and allow the pairing of EET87517 and EET 87720, but the latter two differ petrographically. No other pairings seem likely.

EET83309-38 and GRO95575-17 contain more than 10^{-5} cm^3 STP/g of ^{36}Ar and have ^{20}Ne/^{22}Ne ratios >1, signaling the presence of large concentrations of trapped gas. The non-cosmogenic ^{20}Ne/^{36}Ar ratios range from 0.005 to 0.011, well below the solar ratio (>10). A detailed discussion of the trapped component may be found in [5].

A "Bern" plot (Figure 1) suggests He losses from EET87720, EET 87517, GRA95205, and GRO95575. The differences in He concentration for GRA 95205,32 and ,33 indicate that losses vary on a centimeter scale. The remaining eight ureilites have relatively high (>1.13) ^{22}Ne/^{21}Ne ratios and for six the ratio is >1.17. The generally high absolute ^{22}Ne/^{21}Ne ratios imply that most of our samples were irradiated by galactic cosmic rays (GCR) under 'light' shielding conditions, i.e., as small bodies (<30 cm in radius) or close to the surfaces of larger ones. Modeled values of the GCR cosmogenic ^{22}Ne/^{21}Ne ratio ([6]) are lower than most of the observed values. These differences may imply irradiation by solar cosmic rays (SCR), which can raise ^{22}Ne/^{21}Ne ratios [7], or may relate to various uncertainties.

The average of the 15 measured ^{36}Cl activities is 4.0±0.2 dpm/kg (1-σ mean), a value close to the one expected at saturation from GCR galactic-cosmic-ray irradiation of small to medium size meteoroids. Terrestrial decay may have offset increases in surface production due to solar-cosmic-ray (SCR) irradiation. The case for SCR irradiation is strongest for GRO95575, which has the highest ^{36}Cl activity, 6.2 dpm/kg. The average of 15 measured ^{26}Al activities, 38.8±2.6 dpm/kg (1-σ mean), agrees well with previous work (see **[4]**).

Figure 2 shows the ^{21}Ne CRE ages based on a constant ^{21}Ne production rate, P_{21} [10^{-8} cm^3 STP/(g Ma)] =0.412 in order to facilitate comparison with [1].

Figure 1. Smaller symbols show model calculations [6] for various radii, R## [cm] and average ureilite composition.

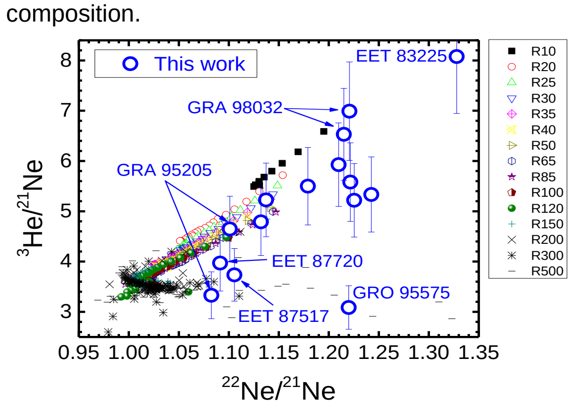
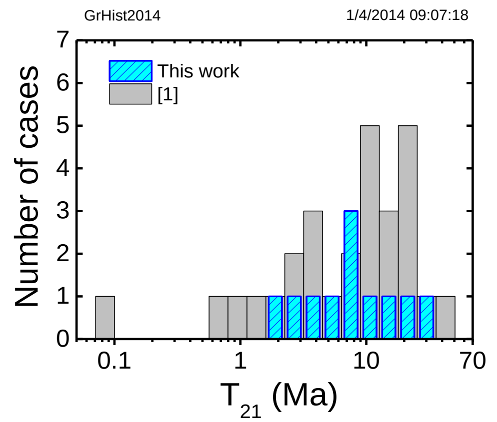


Figure 2.



They range from 1.8 to 33.2 Ma and are consistent with earlier observations [1,8].

Judging from the modeling results of [6], a better average value of P_{21} for ^{26}Al ~ 40 dpm/kg would be lower by about 30% and the CRE ages higher by 30%. This conclusion is reflected in the higher ^{21}Ne-^{26}Al CRE ages ($T_{21\text{-}26}$ [Ma] = ^{21}Ne [10^{-8} cm^3 STP/g]/^{26}Al [dpm/kg] × 13.1) of Table 1. Generally high proportions of trapped Ar in most samples lead to large relative uncertainties in the concentrations of cosmogenic ^{38}Ar$_{cos}$ and the CRE ages derived from them. Even so, the CRE ages based on ^{38}Ar$_{cos}$ are mostly consistent with the ^{21}Ne CRE ages.

Conclusions: Cosmogenic noble gas concentrations and radionuclide activities were measured for 15 samples of 13 distinct ureilites. The results for 8 of them are consistent with small preatmospheric size, ≤30 cm. If calculated with a constant ^{21}Ne production rate of 0.41 × 10^{-8} cm^3 STP/(g Ma), the cosmic-ray exposure ages tend to fall into between 6 and 30 Ma, but light shielding conditions suggest a lower average production rate and CRE ages about 30% higher. Overall, the distribution appears - coincidentally perhaps - most similar to that of the LL-chondrites [1]. Measurements of ^{10}Be and ^{41}Ca should be helpful in learning about the terrestrial ages of and SCR effects in the samples.

References: [1] Herzog G. F. and Caffee M. W. (2014) *Treatise on Geochemistry* 1, 419-454. [2] Goodrich C. A. et al. (2004) *Chemie der Erde*, 64, 283-327. [3] Mittlefehldt D. W. et al., (1998) *Rev. Min. Geochem.*, 36, 4.1-4.195. [4] Aylmer D. et al. (1990) *GCA* 54, 1775. [5] Nagao K. et al. (2014) this conference. [6] Leya I. and Masarik J. (2009) *M&PS* 44, 1061. [7] Wieler R. (2002) *Reviews in Mineralogy and Geochemistry*, 47, 125-170. [8] Cosarinsky M., et al. (2010) *LPSC* 41, 1770.

Table 1. Noble gas concentrations (10^{-9} cm^3 STP/g), ^{36}Cl and ^{26}Al activities (dpm/kg) and ^{21}Ne/^{26}Al CRE ages (Ma) in ureilites.

	^{3}He	^{4}He	^{20}Ne	^{21}Ne	^{22}Ne	^{36}Ar	^{38}Ar	^{40}Ar	^{36}Cl	^{26}Al	$T_{21\text{-}26}$
ALH82106-23	42.3	499	11.6	7.6	9.56	238	45	490	4.50	41.9	2.4
ALH82130-35	42.4	616	14.6	8.2	10.4	462	86	516	4.92	44.8	2.4
ALH84136-36	41.4	636	13.8	7.8	10.1	433	82	480	3.78	44.3	2.3
EET83225-30	97.7	378	14.0	12.1.	16.1	70	14	351	4.84	36.3	4.4
EET83309-38	7214	8479	179.	138.	160.	10756	2007	1782	3.80	28.3	64
EET87511-32	80.8	996	35.8	14.8	19.1	1645	308	629	3.33	33.7	5.7
EET87517-32	121.	1051	35.6	32.4	36.3	296	56	288	3.17	52.9	8.0
EET87720-26	109.	845	26.5	27.4	30.1	208	40	525	3.84	37.5	9.6
GRA95205-32	1579	1162	47.5	47.2	51.4	961	181	675	3.83	25.1	24.6
GRA95205-33	174	1266	44.0	37.4	41.8	1635	308	1275	2.65	27.8	17.6
GRA98032-17	392	1724	66.4	60.0	73.3	1838	347	1272	3.59	31.4	25.1
GRA98032-19	395	1676	63.3	56.6	69.4	1711	326	1039	3.71	25.2	29.4
GRO95575-17	67.4	2133	158.3	22.2	37.2	13801	2598	629	6.19	50.2	5.7
MET1083-5	1697	866	33.7	28.5	34.8	59	12	251	4.01	45.6	8.2
MET1085-5	452	2634	91.2	94.5	107.1	169	37	736	3.57	56.9	21.86

Uncertainties of measured values ~10%.