NOBLE GAS COMPOSITIONS OF SEVEN NORTH WEST AFRICA (NWA) UREILITES.

K. Nagao[1]*, J. Choi[1], J. M. Baek[1], R. Bartoschewitz[2], C. Park[1], J. I. Lee[1], M. J. Lee[1], [1]Korea Polar Research Institute (KOPRI), 26 Songdomirae-ro, Yeonsu-gu, Incheon 21990, South Korea (*e-mail: nagao@kopri.re.kr), [2]Meteorite Laboratory, Weiland 37, D-38518 Gifhorn, Germany.

Introduction: Ureilites are known to have high concentrations of trapped noble gases, and their host phases are thought to be carbonaceous materials such as amorphous carbon, graphite and diamond [e.g., 1–4]. The origin and trapping mechanism of the trapped noble gases in ureilites, however, are still under discussion. We have presented noble gas data on 13 ureilites from Antarctica [5]. Here we present additional noble gas data on 7 ureilites from NWA, which are measured with the same mass spectrometer and the same analytical technique applied to previous ones.

Samples and experimental procedure: Fragments weighing ca. 10–20 mg taken from chips weighing ~100 mg of 7 different ureilites from NWA (North West Africa) were used for noble analyses (Table 1). A noble gas mass spectrometer, modified-VG5400 at KOPRI (Korea Polar Research Institute), was used for noble gas analysis. The mass spectrometer was former modified-VG5400/MS-3 at the University of Tokyo, and used for the analysis of above mentioned Antarctic ureilites [5]. The samples were installed in a sample holder made of low permeability glass to He, and the sample holder was connected to a noble gas extraction furnace. The samples were preheated at 150°C for ~24 hours in ultrahigh vacuum condition to remove atmospheric noble gas contamination. Noble gases were extracted by heating each sample in the furnace at 1800°C for 30 min, and then purified with two Ti-Zr getters kept at the temperature of ca. 800°C and SAES-getters (NP-10). The purified noble gases were separated from each other by using a charcoal trap at the liquid nitrogen temperature and a temperature-controlled cryogenically cooled trap before introducing each noble gas (He, Ne, Ar, Kr, and Xe) into the mass spectrometer. Sensitivities and mass discrimination correction factors were determined by measuring calibrated atmospheric noble gases and ^{3}He-^{4}He mixture. Because of high concentrations of Kr and Xe in the samples, reductions of extracted Kr and Xe amounts before introducing them into the mass spectrometer were applied.

Results and Discussion: Concentrations of all noble gases and isotopic ratios of He, Ne, and Ar for 7 NWA ureilites are presented in Table 1. The noble gas data suggest no pairing among these meteorites. Because of high concentrations of trapped Ar, Kr, and Xe, corrections for cosmogenic isotopes resulted in minor or negligible for isotopic ratios.

Light noble gases. He and Ne are dominated by cosmogenic ones, showing ^{3}He/^{4}He > 0.03 and ^{20}Ne/^{22}Ne < 3. Cosmic ray exposure ages based on the cosmogenic ^{21}Ne concentrations and ^{21}Ne production rate of 4.1×10^{-9} cm^{3}STP/g/Ma by [5] are in the range of 3–19 Ma, consistent with the distribution for the Antarctic ureilites [5]. Cosmogenic ^{3}He concentrations of NWA 3280 and NWA 8168 are, however, much higher than those expected from cosmogenic ^{21}Ne, resulting in unexplainably longer exposure ages T_3, i.e., $T_3/T_{21} \approx 2.5$ for both ureilites. T_3/T_{21} ratios for other meteorites are from 0.6 to 1.5, which might have been caused by He loss or different shielding conditions. Ne isotopic ratios show small contributions of trapped Ne to prevailing cosmogenic Ne. Considering all the ureilites from NWA [this work] and Antarctic ureilites [5], cosmogenic ^{21}Ne/^{22}Ne ratios may be separated into two groups with ca. 0.8 and ca. 0.9. All the Ne data can be considered as mixtures between Ne$_{\text{ureilite}}$, ^{20}Ne/^{22}Ne = 10.5–10.7 and ^{21}Ne/^{22}Ne ≈ 0.032 [1, 2], and Ne$_{\text{cosm}}$ with 0.8 or 0.9 (^{21}Ne/^{22}Ne). Ureilites in the group with low ^{21}Ne/^{22}Ne (0.8) could be derived from small preatmospheric bodies as discussed in [5] that many ureilites would have irradiated at shallow depths or in small meteoroids. The higher ^{21}Ne/^{22}Ne of 0.9 might reflect Ne produced in olivine by GCR or larger meteoroids.

Ar isotopic ratios. Low ^{40}Ar/^{36}Ar$_{\text{trap}}$ ratios, 0.05–9.2, are observed for the ureilites, for which NWA 3232 with the lowest ^{40}Ar/^{36}Ar$_{\text{trap}}$ has the highest ^{36}Ar concentration of 6.1×10^{-6} cm^{3}STP/g. A plot of ^{40}Ar/^{36}Ar$_{\text{trap}}$ against 1/^{36}Ar$_{\text{trap}}$ shows positive correlation indicating very low ^{40}Ar/^{36}Ar ratio originally trapped in ureilites as shown in [6]. Low ^{40}Ar/^{36}Ar ratio of $(2.9 \pm 1.7) \times 10^{-4}$ was reported for Dyalpur ureilite [2]. The apparent increase in ^{40}Ar/^{36}Ar with lower concentration of trapped ^{36}Ar could be an increasing contamination of atmospheric Ar to the samples. An exception is NWA 7290, which has high concentration of ^{40}Ar (1.2×10^{-5} cm^{3}STP/g) and does not follow the trend shown in [6]. This ureilite should have higher concentration of K, ~200 ppm assuming 4 Ga, than the others.

Abundance ratios of Ar, Kr and Xe. Positive correlation in a plot between ^{36}Ar$_{\text{trap}}$/^{132}Xe and ^{84}Kr/^{132}Xe as shown in [6] is observed. The correlation among the abundance ratios is in good agreement with the reported correlation [e.g., 2, 3, 6], although the spread for

NWA ureilites in this work extends to higher plotted area compared with those for Antarctic ureilites [6]. The positive correlation is explained as a selective loss of lighter noble gases Ar and Kr than Xe, resulted in low Ar/Xe and Kr/Xe ratios [2, 3]. Samples, NWA 3232, NWA 7290, and NWA 8168, which have higher $^{36}Ar_{trap}/^{132}Xe$ and $^{84}Kr/^{132}Xe$ ratios than the others, seem to support the hypothesis, although composition of originally trapped heavy noble gases in ureilites is still unclear.

Kr and Xe isotopic compositions. Figs. 1 and 2 are plots of $^{130}Xe/^{132}Xe$ vs. $^{136}Xe/^{132}Xe$ and $^{82}Kr/^{84}Kr$ vs. $^{80}Kr/^{84}Kr$, where some endmembers, addition of HL-Kr, HL-Xe, and fissiogenic Xe from ^{244}Pu to Q-Xe are indicated. Unpublished data measured in our laboratory with the same analytical technique are also plotted for comparison. Ureilite Xe data (Fig. 1) are plotted close to Q, but most data points shift slightly from Q to solar component or higher $^{130}Xe/^{132}Xe$. Contribution of HL-Xe to ureilite Xe is negligible. This is clearly different from those for Murchison and other C-chondrites, which shift to addition of HL-Xe.

Most ureilite Kr data points in Fig. 2 also plot close to Q-Kr, overlapping the Murchison data points within error ranges, although slightly shit to lower left from Q. The shift from Q-Kr for Murchison is consistent with that for Xe (addition of HL) as shown in Fig. 1. Kr plots in wider range, from ureilite-Kr to lower left of Q. Because Xe isotopic ratios of ureilites do not indicate a presence of HL-Xe, the Kr data points plot to lower left from Q could be a small contribution of Kr of solar origin as also indicated in Xe plots (Fig. 1).

References: [1] Wacker J. F. (1986) *GCA* 50, 633–642. [2] Göbel R. et al. (1978) *JGR* 83, 855–867. [3] Okazaki R. et al. (2003) MAPS 38, 767–781. [4] Cosarinsky M. et al. (2010) *41st LPSC*, Abstract #1770. [5] Park J. et al. (2014) *45th LPSC*, Abstract #1618. [6] Nagao K. et al. (2014) *45th LPSC*, Abstract #2016. [7] Choi J. et al. (2017) *48th LPSC*, Abstract (submitted).

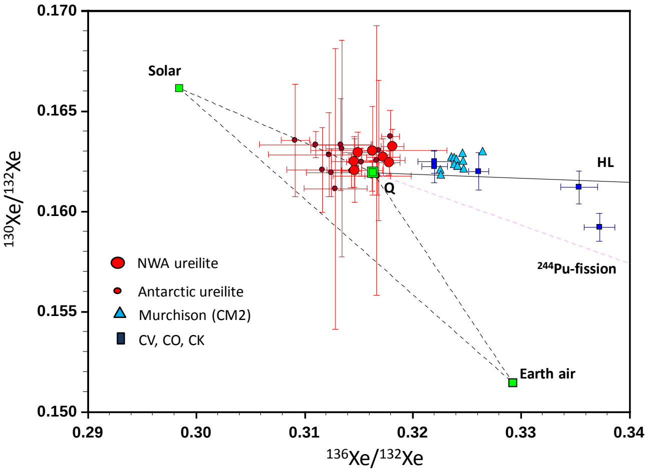

Fig. 1. $^{130}Xe/^{132}Xe$ ratios are plotted against $^{136}Xe/^{132}Xe$ ratios. Mixing lines between Q-Xe and HL-Xe, and Q-Xe and Xe produced by fission of ^{244}Pu are shown. Unpublished data for Antarctic ureilites, Murchison, and some carbonaceous chondrites (CV, CO, CK) [7] are plotted for comparison. All samples have been measure in our laboratory with the same machine and the same analytical technique.

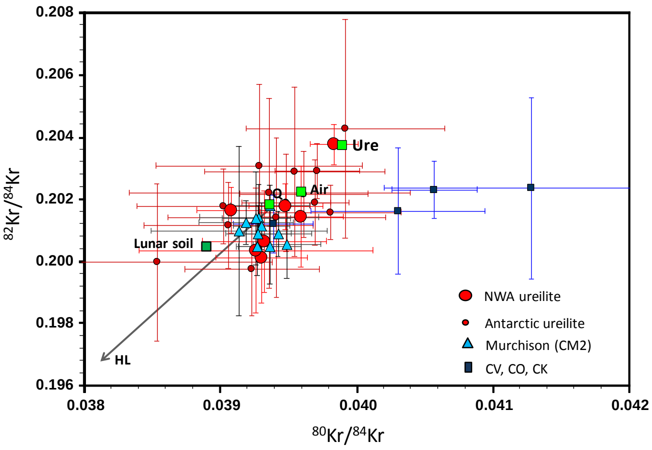

Fig. 2. $^{82}Kr/^{84}Kr$ ratios are plotted against $^{80}Kr/^{84}Kr$ ratios. For the data of Antarctic ureilites, Murchison, and some carbonaceous chondrites (CV, CO, CK), see caption of Fig. 1.

Table 1. He, Ne and Ar isotopic ratios, and concentrations of noble gases in NWA ureilites.

Meteorite	Weight	^{4}He	$^{3}He/^{4}He$	^{20}Ne	$^{20}Ne/^{22}Ne$	$^{21}Ne/^{22}Ne$	^{36}Ar	^{40}Ar	$^{38}Ar/^{36}Ar$	$^{40}Ar/^{36}Ar$	^{84}Kr	^{132}Xe
	mg	10^{-9}cc/g		10^{-9}cc/g			10^{-9}cc/g				10^{-12}cc/g	
NWA 3232 (Ure)	12.45	3333	0.03041	85.3	3.1382	0.6908	6099	284	0.1880	0.05	16171	5418
		± 334	± 0.00017	± 8.5	± 0.0062	± 0.0014	± 610	± 57	± 0.0006	± 0.01	± 1619	± 542
NWA 3280 (Ure)	14.99	1844	0.33915	67.7	0.8159	0.8042	85	305	0.2224	3.59	445	374
		± 185	± 0.00187	± 6.8	± 0.0020	± 0.0015	± 9	± 51	± 0.0008	± 0.47	± 47	± 38
NWA 3290 (Ure)	14.27	270	0.09030	13.0	0.9652	0.7881	600	388	0.1894	0.65	4841	8881
		± 27	± 0.00064	± 1.3	± 0.0057	± 0.0023	± 60	± 58	± 0.0006	± 0.07	± 486	± 889
NWA 7290 (Ure)	18.73	361	0.16300	45.2	1.9448	0.8007	1317	12144	0.1900	9.22	6787	2627
		± 36	± 0.00097	± 4.5	± 0.0087	± 0.0013	± 132	± 1215	± 0.0006	± 0.03	± 680	± 263
NWA 7294 (Ure)	15.91	1776	0.15428	74.4	0.8904	0.9158	1066	1019	0.1907	0.96	7837	9322
		± 178	± 0.00089	± 7.4	± 0.0026	± 0.0012	± 107	± 109	± 0.0006	± 0.04	± 786	± 933
NWA 8167 (Ure)	14.56	289	0.22792	13.4	0.8596	0.9146	61	369	0.1947	6.04	671	600
		± 29	± 0.00149	± 1.3	± 0.0045	± 0.0021	± 6	± 55	± 0.0007	± 0.67	± 69	± 61
NWA 8168 (Ure)	18.89	808	0.26720	31.9	1.0601	0.7804	2112	996	0.1895	0.47	11060	9010
		± 81	± 0.00151	± 3.2	± 0.0030	± 0.0014	± 211	± 105	± 0.0006	± 0.02	± 1108	± 901