^{14}C AGES OF ANTARCTIC METEORITES AND ICE AND THE COMPOSITION OF THE AIR TRAPPED IN THE ICE, E.L. Fireman and T. Norris, Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA 02138

The terrestrial ages of Antarctic meteorites and ice and the composition of gas trapped in ice are aids in understanding the meteorite collection process and the history of Antarctica. Antarctic meteorite ages older than $\sim 100 \times 10^{3}$ yr are determined by cosmic-ray-produced ^{26}Al, ^{53}Mn, and ^{36}Cl (1-4); meteorite ages younger than $\sim 40 \times 10^{3}$ yr are determined by ^{14}C (5-7). Most ALHA meteorites fell less than 200×10^3 yr ago. Of ten ALHA meteorites analyzed for ^{14}C, three (77256, 77003, and 77294) had ages of $(11 \pm 1) \times 10^3$, $(21\, ^{+4}_{-3}) \times 10^3$, and $(30 \pm 2) \times 10^3$ yr, respectively; the others had ^{14}C limit ages, mainly older than 30×10^3 yr. Table 1 gives ^{14}C and CO_2 data and terrestrial and weathering ages for two H chondrites, 77004 and 77294, that we recently measured. The terrestrial age (5-7) is obtained by comparing the ^{14}C activities in 1000°C and melt extractions of CO_2 with those of Bruderheim. The weathering age (5-7) is estimated from the specific activity of the CO_2 extracted at 500°C after an overnight bake-out at 100°C. The ^{14}C terrestrial age of 77294 can be determined more accurately than that of 77004 because of its smaller carbon content.

Table 1. Amounts of CO_2 and ^{14}C and ages of ALHA 77294 and 77004.

	(10.5 g) ALHA 77294 (A, A)*			(10.0 g) ALHA 77004 (C, C)*		
Extract. Temp. °C	CO_2 (cm^3 STP)	^{14}C (dpm/kg)	Age (10^3 yr)	CO_2 (cm^3 STP/kg)	^{14}C (dpm/kg)	Age (10^3 yr)
500	1.34	<0.2	(>13)†	8.6	<0.8	(>17)†
1000	1.04	0.6 ± 0.2	30 ± 2	5.4	<0.7	>32
Melt	0.28	1.0 ± 0.1		4.5	<0.7	
Remelt	0.10	<0.2	–	3.5	<0.5	–

*Weathering classification.
†Weathering age.

The age of Allan Hills ice combined with a knowledge of ice movement to the region gives the area on which the ALHA meteorites fell. The fall area together with the terrestrial ages of the associated meteorites give the fall rate. We study the gas in ice samples from Allan Hills and from Byrd core, a ~2000-m core taken at the Byrd site. The gas in the ice is useful for ^{14}C and other types of age determination. The composition of the gas is interesting for its bearing on the melting history of the ice and the composition of the ancient atmosphere. The Byrd core has been studied extensively (8-11) and is excellent material for comparisons of our work with previous studies. The comparison of Byrd ice (a snow accumulation region) with Allan ice (an ice ablation region) is also of importance.

Pieces of ice are put in a 6-in.-diameter glass pipe that is sealed to an extraction unit. The pipe is evacuated and flushed with He. Gas adsorbed on the surface of the ice is removed by sweeping He over the ice. The sweeping procedure melts the surfaces (5 to 10% of the mass) and purges this melt of its gas. The remaining ice is then melted in a He atmosphere and the melt water purged with He. The purging procedure extracts all gaseous constituents (≥ 95%). CO_2 is collected in a glass trap at -196°C; the other constituents in a sieve (5A) at -196°C. The collected gases are measured volumetrically and stored. The water is then acidified to a pH of 1 using either sulfuric or nitric acid, heated to 55°C, and purged again to ensure that CO_2 is collected

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from carbonates. The pH of Antarctic ice is 5.5. The first three samples that were studied (362 and 363 m Byrd core and Allan Hills surface ice from stake 12) were acidified before purging. Table 2 gives our results.

Table 2. Antarctic ice gas content, composition, and ^{14}C activity.

Sample (loc, depth, wgt.)	Extraction (temp, pH)	Gas (cm^3/kg)	N_2 %	O_2 %	Ar %	$\delta(^{15}N/^{14}N)$ ‰	CO_2 %	$^{14}C/CO_2$ (10^{-3} dpm/cm^3)	^{14}C age (10^3 yr)
Byrd 271 m	24°C, 5.5	66.8	79.3 ± 0.9	20.0 ± 0.6	0.91 ± 0.05	3.3 ± 0.5	0.0336	6.8 ± 1.0	1.0 ± 1.0
7.6 kg	55°C, 1	0.1	–	–	–	–			
Byrd 272 m	24°C, 5.5	57.5	77.9 ± 0.7	20.7 ± 0.4	0.93 ± 0.05	1.3 ± 0.7			
8.8 kg	55°C, 1	0.1	–	–	–	–			
Byrd 362 m	24°C, 1	74.3	79.3 ± 0.7	20.0 ± 0.5	0.95 ± 0.05	-0.5 ± 0.6	0.051	6.0 ± 0.5	2.0 ± 0.7
6.2 kg	55°C, 1	0.5	–	–	–	–			
Byrd 363 m	24°C, 1	69.3	77.7 ± 1.0	19.1 ± 0.3	0.85 ± 0.05	-0.1 ± 0.6			
8.0 kg	55°C, 1	1.3	–	–	–	–			
Byrd 1068 m	24°C, 5.5	117.8	77.0 ± 0.7	21.1 ± 0.1	0.86 ± 0.05	3.0 ± 0.7	0.0216	–	–
9.2 kg	55°C, 1	0.2	–	–	–	–			
Byrd 1071 m	24°C, 5.5	101.2	78.6 ± 0.6	19.5 ± 0.4	0.91 ± 0.05	4.0 ± 1.2	0.0356	≤3.0	≥8.0
6.2 kg	55°C, 1	7.5	–	–	–	–			
Byrd 1469 m	24°C, 5.5	115.1	78.2 ± 0.9	21.2 ± 0.6	0.70 ± 0.04	1.0 ± 0.6	0.0237	–	–
9.5 kg	55°C, 1	0.4	–	–	–	–			
A.H.$_{12}$, sur.	24°C, 1	47.0	77.4 ± 0.7	20.7 ± 0.4	0.90 ± 0.05	0.7 ± 0.5	0.187	27 ± 3	nuclear debris
31 kg	55°C, 1	0.9	–	–	–	–			
A.H.$_{18}$, sur.	24°C, 5.5	20.1	77.6 ± 0.8	19.6 ± 0.6	0.95 ± 0.04	1.0 ± 0.7	0.129	25 ± 6	nuclear debris
16.6 kg	55°C, 1	0.4	–	–	–	–			
A.H., 5-25 cm	24°C, 5.5	46.0	79.6 ± 1.0	19.8 ± 0.6	1.00 ± 0.06	1.3 ± 0.3	0.054	7.0 ± 3.0	≤6
12.9 kg	55°C, 1	1.5	–	–	–	–			
Frozen water	24°C, 5.5	20.4	71.8 ± 1.2	26.5 ± 0.9	1.30 ± 0.08	0.6 ± 0.4	1.35	8.7 ± 0.5	0 ± 0.7
7.8 kg	55°C, 1	0.06	–	–	–	–			
Air		–	78.0 ± 0.6	20.7 ± 0.3	0.93 ± 0.05	0.0	0.034	–	–

The amounts of gas minus CO_2 ranged from 58 to 118 cm^3 STP/kg for the Byrd core and from 21 to 48 cm^3 STP/kg for the Allan Hills ice samples. Analyses for N_2, O_2, Ar, and $^{15}N/^{14}N$ were done by converting the O_2 to CO_2 over a hot carbon filament, measuring volumes, and studying the N_2 + Ar fraction with a mass spectrometer. For the Antarctic samples, the N_2, O_2, and Ar abundances and the $^{15}N/^{14}N$ ratios were the same as air; the deviations in Ar abundances and $^{15}N/^{14}N$ ratios outside of experimental error require further investigation. The gas from frozen distilled water had a very high CO_2 abundance (1.35%), high O_2 and Ar abundances (26.5% and 1.3%, respectively), and a low N_2 abundance (71.8%), which typifies dissolved air. The high CO_2 abundances in the Allan Hills surface samples from stakes 12 and 18 (0.187 and 0.129%, respectively) are attributed mainly to dissolved air because melting and refreezing occurs on Allan Hills surface ice. The CO_2 abundance in the subsurface Allan Hills ice (5 to 25 cm depth) is 0.054%; this value is similar to the 0.051% abundance in Byrd ice from 362- and 363-m depths, and is probably caused by a CO_2 contribution from carbonates. At 1068- and 1469-m depths in Byrd ice, the CO_2 abundances, 0.0216 and 0.0237%, are low; this result can be only explained by a low CO_2 abundance in the ancient atmosphere.

The CO_2 is counted in low-level proportional minicounters and the specific activities compared with NBS oxalic acid standards. The ^{14}C ages of the 272-, 363-, and 1071-m Byrd core samples, $(1 \pm 1) \times 10^3$, $(2.0 \pm 0.7) \times 10^3$, and $(> 8.0) \times 10^3$ yr are consistent with their calculated ages (10, 11). The Allan Hills surface samples have specific activities 3 to 4 times that of the oxalic acid indicating the presence of nuclear debris. The Allan Hills sample taken from 5- to 25-cm depth between stakes 10 and 11 had a ^{14}C age of less than 6×10^3 yr.

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