CHEMISTRY LETTERS, pp. 371-374, 1993.

Carbon Isotopic Compositions in Antarctic Carbonaceous Chondrites

Akira SHIMOYAMA,* Hiroshi NARAOKA,†† Osamu MATSUBAYA,† and Kaoru HARADA†††
Department of Chemistry, University of Tsukuba, Tsukuba 305
† Research Institute of Natural Resources, Mining College, Akita University, Akita 010

Total carbon contents and carbon isotopic compositions ($\delta^{13}C$ relative to PDB) in 33 specimens of Antarctic carbonaceous chondrites are in the ranges of 0.02 to 2.49% and -16.9 to +0.9‰ with the mean values 1.31% and -5.8‰, respectively. The value -5.8‰ is very close to that for the average juvenile mantle carbon but is 5.7‰ higher than that for non-Antarctic ones.

The number of Antarctic meteorites now exceeds 11000 since the discovery of 1969. Among these, more than 8500 meteorites belong to the National Institute of Polar Research (NIPR), Japan, and include approximately 100 carbonaceous chondrites some of which are available for examination.[1]

Carbonaceous chondrites are the most primitive of all meteorites formed in the early solar system. They contain carbon compounds and, therefore, provide various informations on the primordial carbon on the Earth. Furthermore, they are the only primitive material of our solar system available for laboratory examination. We reported total carbon and nitrogen contents in ten Antarctic carbonaceous chondrites (eleven specimens from NIPR).[2] That work has been extended to 25 chondrites (34 specimens from NIPR) for the analyses of stable carbon isotopic compositions ($^{13}C/^{12}C$). The number of specimens analyzed so far are probably enough to draw characteristic features of the carbon contents and the isotopic compositions for Antarctic carbonaceous chondrites. Total carbon contents and the isotopic compositions were summarized for 35 non-Antarctic carbonaceous chondrites (62 specimens).[3] Therefore, it is possible to compare these values between Antarctic and non-Antarctic carbonaceous chondrites.

For each specimen, about 200 mg of a few chips were taken and pulverized carefully in a clean room. The determinations of the total carbon contents were carried out in duplicate in the usual manner by a CHN analyzer (Perkin Elmer 240) using 5 to 12 mg of the pulverized samples as described in the previous study.[2] Each content is expressed as an average of the duplicate. The same pulverized specimens were examined for the carbon isotopic compositions using 20 to 150 mg depending on the carbon contents obtained prior to the examination.

---

†† Present address: Institute of Mineralogy, Petrology and Economic Geology, Faculty of Science, Tohoku University, Sendai 980.
††† Present address: Shôin Women's University, Nada-ku, Kobe 653.

The analytical procedures were the same as those used in our previous study of the oldest terrestrial sediments.[4] Briefly, the samples were combusted at 900 °C under O_2 atmosphere. Among the gases generated, CO_2 was purified, recovered and analyzed on a mass spectrometer (Varian MAT 250). The results are shown by $\delta^{13}C$ per mil from the Peedee Belemnite (PDB) standard.

The carbon contents (C) and the $\delta^{13}C$ values are listed in Table 1. The number after the comma in a chondrite name shows a specimen number for a portion of the chondrite. Thus, four specimens from different portions were analyzed for the Yamato-791198 chondrite and two specimens for several chondrites. The analytical errors are generally ±0.03% for the carbon contents and ±0.1‰ for the $\delta^{13}C$ values. Therefore, the differences in carbon content and $\delta^{13}C$ value within a single chondrite are largely due to the heterogeneity of the chondrite. However, the largest difference in $\delta^{13}C$ value is only 2.5‰ found in the Asuka-6 chondrite (Nos. 24 and 25), so that the heterogeneity in a chondrite does not make a problem in this study. In carbonaceous chondrites the most abundant carbon bearing component is organic matter (mostly solvent-insoluble macromolecular material with a minor amount of solvent-soluble compounds) followed by a minor amount of carbonate. There is also an extremely small amount of exotic components such as amorphous carbon, diamond and silicon carbide.[7] The silicon carbide combusts above 1000 °C and shows $\delta^{13}C$ > +1000‰. However, its contribution to the total value is mostly negligible because of the small abundance.

Table 1. Carbon contents and carbon isotopic compositions in Antarctic carbonaceous chondrites

No.	Specimen	Type	C/wt %	$\delta^{13}C$/‰[a)]	No.	Specimen	Type	C/wt %	$\delta^{13}C$/‰
1	Yamato-74135,61	CO3	1.08[c)]	-6.4	18	Yamato-82094,92	CO3	0.14	-11.8
2	Yamato-74642,95	CM2	1.94[c)]	-7.2	19	Yamato-82098,81	CM2	1.67	-0.5
3	Yamato-74662,79	CM2	1.91[c)]	-6.6	20	Yamato-82162,90	CI	2.36	-16.9
4	Allan Hills-77003,99	C3	0.29	-11.6	21	Yamato-86720,87	CM	0.67	-15.1
5	Allan Hills-77307,88	CO3	0.79[c)]	-8.3	22	Asuka-2,20	CM2	2.46	-13.4
6	Yamato-791198,22	CM2	2.32[d)]	+0.6	23	Asuka-2,52	CM2	2.49	-12.8
7	Yamato-791198,60	CM2	2.30	-0.3	24	Asuka-6,20	CM2	1.49	-6.9
8	Yamato-791198,73	CM2	2.26[d)]	+0.1	25	Asuka-6,52	CM2	1.28	-4.4
9	Yamato-791198,82	CM2	1.99	-0.9	26	Asuka-14,20	CM2	1.77	-2.6
10	Yamato-791717,91	CO3	0.21[c)]	-13.1	27	Asuka-14,52	CM2	1.59	-2.2
11	Yamato-793321,4	CM2	1.66[e)]	-1.1	28	Asuka-21,52	CV3	0.02	n.d.[b)]
12	Yamato-793321,5	CM2	1.69[e)]	-1.7	29	Asuka-23,54	CM2	1.19	-4.0
13	Belgica-7904,2	CM2	1.13[e)]	-14.0	30	Asuka-24,52	CR or CV	0.16	-3.6
14	Belgica-7904.3	CM2	0.88[e)]	-14.7	31	Asuka-26,53	CO3	0.34	-8.0
15	Yamato-81021,90	CO3	0.89[c)]	-8.4	32	Asuka-27,52 (53)	CI	0.08	(-11.9)
16	Yamato-82042,59	CM1	1.69	+0.9	33	Asuka-42,53	CM2	0.85	-9.1
17	Yamato-82054,81	CM2	1.71	-3.8	34	Asuka-47,52 (53)	CO3	0.08	(-3.4)

a) The $\delta^{13}C$ value in parenthesis corresponds the specimen number in parenthesis.

b) n.d.; not determined. c) Ref. 2. d) Ref. 5. e) Ref. 6.

Among the chondrites examined the carbon contents vary from 0.02 to 2.49% and the $\delta^{13}C$ values from -16.9 to +0.9‰. These values are plotted in Fig. 1. The carbon isotopic compositions are significantly different, suggesting that the chondrites are from either many parent bodies with differing isotopic compositions or a few bodies with many isotopically-different portions. Although not well resolved in Fig. 1, the CM group falls mainly between the two dashed lines except the Asuka-2 chondrite (Nos. 22 and 23). On the other hand, the CO, CV, and CR groups show the carbon contents less than 1% and the $\delta^{13}C$ values from -3 to -13‰.

The mean values of the specimens (except No. 28) show 1.31% for carbon content and -5.8‰ for the $\delta^{13}C$. The value -5.8‰ is obtained by taking a same weight of each specimen, using the following equation,

$$\delta^{13}C_{mean} = \Sigma\,(C_{specimen} \times \delta^{13}C_{specimen}) / n \times C_{mean}$$

where n is the total number (33) of the specimens and C_{mean} is 1.31%. On the other hand, the non-Antarctic carbonaceous chondrites show the carbon contents from 0.1 to 8.46% and the $\delta^{13}C$ values from -25.2 to 0‰ with 1.96% for the C_{mean} and -11.5‰ for the $\delta^{13}C_{mean}$ using the data in Ref. 3. We omitted the data of the Essebi chondrite because the specimen was a "matrix separate" rather than a bulk specimen, and of a "Dark inclusion" of the Allende chondrite because of the same reason as Essebi in the calculation for the non-Antarctic ones.

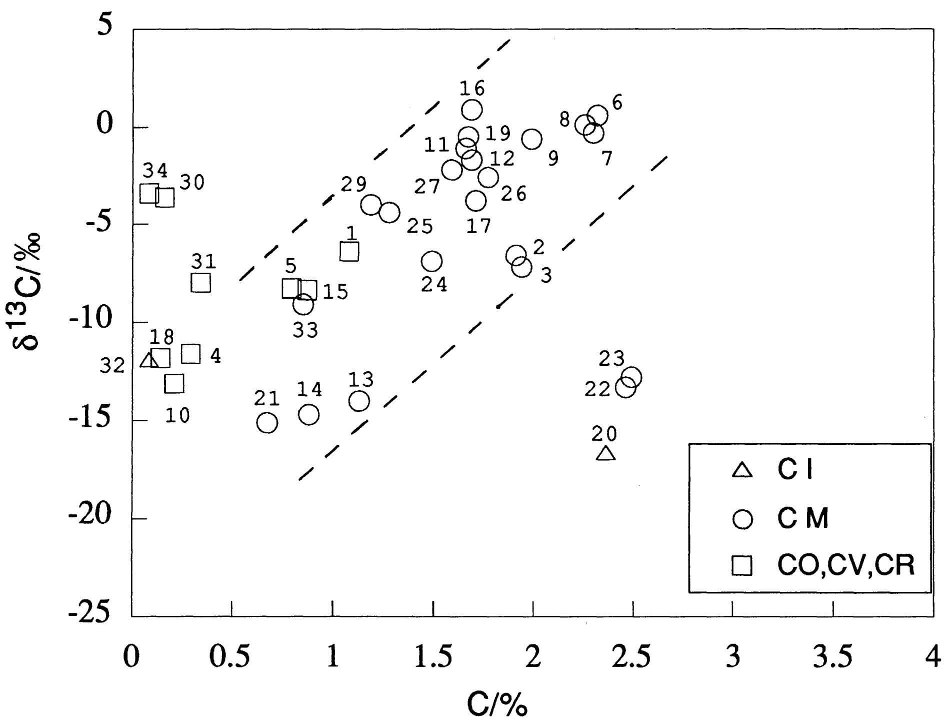

Fig. 1. Plot of carbon contents vs. carbon isotopic compositions in Antarctic carbonaceous chondrites. The number for a mark corresponds the specimen number in Table 1.

The value -5.8‰ for the Antarctic carbonaceous chondrites is very close to the average value (-5.0 ± 1.5‰) reported for the juvenile mantle carbon[8] and the values (-5.0, -5.2, and -5.6‰) for the carbonate carbon in the oldest terrestrial sediments (3.8 x 10^9 y) in the Isua area.[4] However, the value (-11.5‰) for the non-Antarctic ones is notably different from that for the Antarctic ones and those for the primitive carbon.

The apparent difference in the mean $\delta^{13}C$ values for the Antarctic and non-Antarctic carbonaceous chondrites may be explained by either or both of the following explanations: 1) The Antarctic chondrites have a different parent population from that of the non-Antarctic ones. Studies on a significant number of Antarctic meteorites collected over the past 20 years has raised a suggestion that there might be a difference between the parent populations of Antarctic and non-Antarctic meteorites (see an assessment[9]). Earth has collected Antarctic meteorites over the last several 10^5 years, while non-Antarctic ones only over the last several 100 years. 2) The Antarctic chondrites are less contaminated by terrestrial organic matter than the non-Antarctic ones. Terrestrial organic contamination generally increases the carbon content and lowers the $\delta^{13}C$ value. However, the Antarctic chondrites generally show smaller carbon contents and higher $\delta^{13}C$ values than the non-Antarctic ones. Antarctic meteorites had fallen on and stayed in Antarctic ice shield (extremely terrestrial organic-free environment) during the most of their terrestrial time.

A study of detail carbon isotopic compositions on carbonaceous chondrites (twelve Antarctic and ten non-Antarctic ones) concluded that there were no gross differences in carbon chemistry between the Antarctic and non-Antarctic chondrites.[10] This study also pointed out that the terrestrial weathering formed carbonates on the surface of some Antarctic chondrites and the carbonates showed the $\delta^{13}C$ value about 0‰ that is lower than that of the indigenous carbonates (> +20‰). It is possible that the weathering might have acted on some Antarctic chondrites we studied. However, the content of carbonates in carbonaceous chondrites is minor; hence the influence is insignificant to the $\delta^{13}C$ value of the total carbon in the chondrites we studied.

This work was partly supported by the Grant-in-Aid for Scientific Research on Priority Area (Interstellar Substance and Its Evolution, No. 04233204) from the Ministry of Education, Science and Culture, Japan and a research grant from the National Institute of Polar Research, Japan.

References

1) K. Yanai, National Institute of Polar Research, Japan, Personal communication.
2) A. Shimoyama, K, Harada, and K. Yanai, Chem. Lett., 1987, 2013.
3) J. F. Kerridge, Geochim. Cosmochim. Acta, 49, 1707 (1985).
4) A. Shimoyama and O. Matsubaya, Chem. Lett., 1992, 1205.
5) A. Shimoyama, K. Harada, and K. Yanai, Chem. Lett., 1985, 1183.
6) A. Shimoyama and K. Harada, Geochem. J., 18, 281(1984).
7) T. Ming and E. Anders, Geochim. Cosmochim. Acta, 52, 1235 (1988).
8) P. Deines and D. P. Gold, Geochim. Cosmochim. Acta, 37, 1709 (1973).
9) C. Koeberl and W. A. Cassidy, Geochim. Cosmochim. Acta, 55, 3 (1991).
10) M. M. Grady, I. P. Wright, and C. T. Pillinger, Geochim. Cosmochim. Acta, 55, 49 (1991).

(Received October 15, 1992)