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# Carbon and Nitrogen Contents of Carbonaceous Chondrites and Their Implications for a Primitive Condensate in the Early Solar System

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We found that C vs. N contents in Antarctic carbonaceous chondrites can be approximated by the equation, log N = a log C - b. Extrapolating the equation, we estimated that over 80% of a condensate more primitive than C1 chondrites, consist of organic matter and water.

Carbon and nitrogen in carbonaceous chondrites occur mostly as organic compounds. We have analyzed total C and N contents in carbonaceous chondrites from Antarctica, and present here the results and their implications for an estimation of chemical composition of an early solar system condensate.

A total of about 200 mg of a few fragments from each carbonaceous chondrite was powdered in a clean room. Carbon and nitrogen contents were determined on the same aliquot of each sample in the usual manner by a CHN analyzer(Perkin Elmer 240), using 5 to 12 mg aliquots of powdered sample. These analyses were duplicated and the results are listed in Table 1.

Table 1. Carbon and nitrogen contents of Antarctic carbonaceous chondrites

| No. | Chondrites | Group | Carbon content/wt% | Nitrogen content/wt% | C/N Ave |
|---|---|---|---|---|---|
| 1 | Yamato-791198[4)] | CM2 | 2.33, 2.31 | 0.12, 0.13 | 19 |
| 2 | Yamato-74662 | CM2 | 1.94, 1.94 | 0.13, 0.13 | 15 |
| 3 | Yamato-74642 | CM2 | 1.91, 1.91 | 0.11, 0.10 | 18 |
| 4 | Yamato-793321[10)] | CM2 | 1.63, 1.68 | 0.12, 0.11 | 14 |
| 5 | Yamato-82042 | CM1 | 1.71, 1.67 | 0.065, 0.069 | 25 |
| 6 | Belgica-7904.2[10)] | CM2 | 1.13, 1.12 | 0.062, 0.066 | 18 |
| 7 | Belgica-7904.3[10)] | CM2 | 0.87, 0.89 | 0.041, 0.048 | 20 |
| 8 | Yamato-74135 | CO3 | 1.08, 1.08 | 0.033, 0.033 | 33 |
| 9 | Allan Hills-77307 | CO3 | 0.79, 0.79 | 0.023, 0.027 | 32 |
| 10 | Yamato-81021 | CO3 | 0.89, 0.88 | 0.018, 0.016 | 52 |
| 11 | Yamato-791717 | CO3 | 0.21, 0.20 | 0.002, 0.002 | 100 |

The total C and N contents of eleven carbonaceous chondrites from Antarctica are plotted in Fig. 1. A least-squares fit through the data for eleven Antarctic carbonaceous chondrites plotted gives the following equation:

$$\log N = 1.84 \log C - 1.46 \qquad (1)$$

where C and N are concentrations(%) of carbon and nitrogen respectively, and the correlation coefficient(r) is 0.97. The line in Fig. 1 was drawn using Eq. 1. We note that the concentrations of the sample No. 11 are the most crucial values to define Eq. 1 and the coefficient.

If we use 63 sets of data[1,2] of non-Antarctic carbonaceous chondrites, the equation becomes,

$$\log N = 1.34 \log C - 1.61 \qquad (2)$$

where r is 0.90. Apparently, a better relation in log C vs. log N exists in Antarctic carbonaceous chondrites. It is known that Antarctic carbonaceous chondrites are less contaminated by terrestrial organic matter as observed by amino acid examination of Yamato-74662[3] and Yamato-791198.[4]

Non-Antarctic carbonaceous chondrites show a large discontinuity between C2 and C3 chondrites as shown in C-N diagrams.[1,2] However, three Antarctic chondrites, Belgica-7904(No. 7), Yamato-74135(No. 8) and Allan Hills-77307(No. 9), appear in the gap as seen in Fig. 2. Consideration of data for both Antarctic and non-Antarctic chondrites leads to a conclusion that the C and N contents change almost continuously from C1 to C3, if sufficient numbers of carbonaceous chondrites are examined.

These equations show that the C/N ratio is not constant for carbonaceous chondrites, but increases with decreasing amounts of C and N. Grouping the carbonaceous chondrites according to the C/N ratio fits the classification of the chondrites.[5] However, the ratio can not subdivide C3 into CO3 and CV3 as proposed by the petrographic study.[6] The distribution pattern of C1, C2, and C3 along the line suggests that the boundary ratio is about 11 between C1

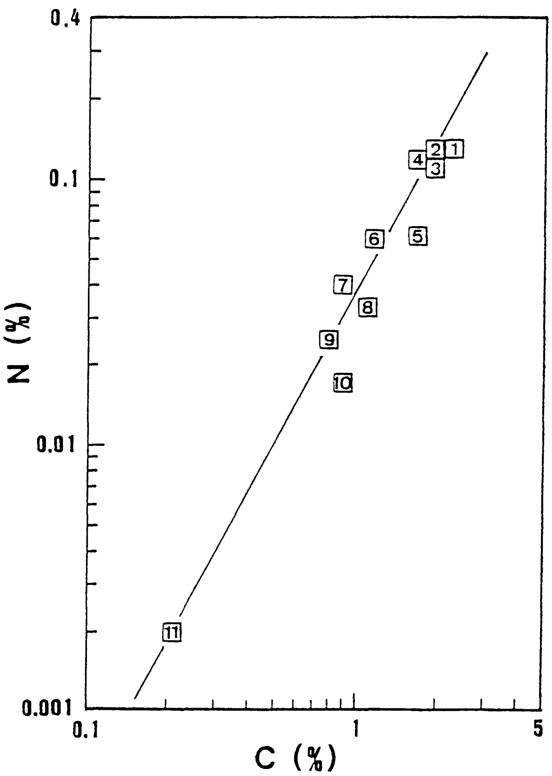


Fig. 1. Carbon and nitrogen contents of Antarctic carbonaceous chondrites. The number in an open square corresponds to that appeared in Table 1.

and C2, and about 25 between C2 and C3 as shown in Fig. 2. Therefore, the C/N ratio probably reflect the temperature history of a carbonaceous chondrite, i.e. the lower the ratio is, the lower the maximum temperature the chondrite experienced is. Accordingly, the distribution pattern of C1, C2, and C3 chondrites suggests that the very primitive condensate is represented by the upper part of the line in Fig. 2.

We applied Eq. 1 to an estimation of C and N contents in the postulated primitive condensate. This application specifies to assume that the condensate was formed by all elements in proportion to the solar abundances[7,8] excluding hydrogen and rare gases, since the abundances of non-volatile elements in carbonaceous chondrites were adapted to the solar abundances. The C/N ratio by weight is 2.70 from Ref. 7 and 4.18 from Ref. 8. Applying the ratio, 2.70 to Eq. 1 gives concentrations of 17.0% C and 6.3% N(10.1% C and 2.4% N from Ref. 8 and hereafter, the percentages shown in the parentheses are obtained from Ref. 8) for the condensate. Once these contents are determined, those of other elements in the condensate may be calculated from the solar abundances, based on the same conversion rate as C and N. The result of the calculation gives a total 80%(44%) for the condensate.

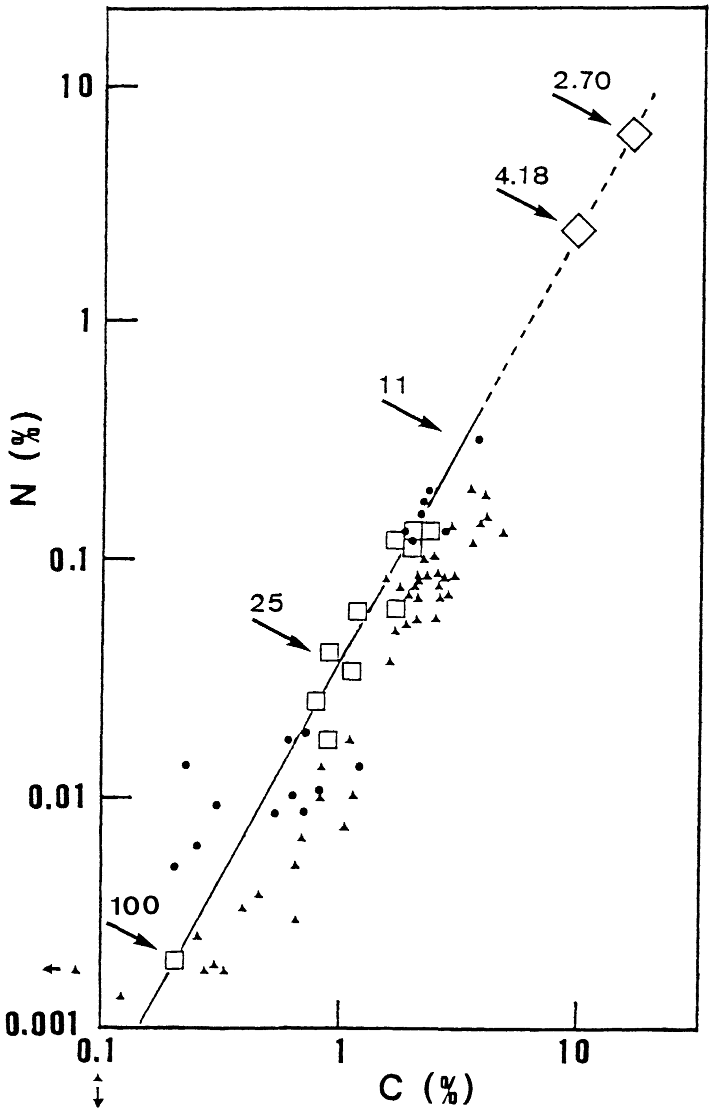


Fig. 2. Carbon and nitrogen contents of carbonaceous chondrites and the postulated primitive condensate. The points of Antarctic carbonaceous chondrites and the line are same as appeared in Fig. 1. The points of non-Antarctic ones are shown by from Ref. 1 and from Ref. 2. The number by arrow shows the C/N ratio on the line. The points, C/N = 2.70 and 4.18 are for the primitive condensate.

The calculation shows 20% (56%) deficiency in the total of the condensate. This deficiency may be filled partly by the introduction of hydrogen which was excluded earlier from the estimation. If the entire solar system abundance of oxygen were combined with hydrogen to form water, a further 5.2%(2.8%) of the condensate would be supplied by hydrogen, increasing the total now to 85%(47%). If, in addition to water formation, carbon and nitrogen were hydrogenated to form $CH_4$ and $NH_3$, 12.2%(6.7%) are needed for hydrogen, and the total changes to 92%(51%) for the condensate. There is no way to estimate the contents of gaseous hydrogen and rare gases for the condensate. These gases would contribute to fill the deficiency to a certain extent.

The solar abundances of Ref. 7 give a better result for the estimation than that of Ref. 8. This result does not indicate that the solar abundances of Ref. 7 are better determined, but derives from the assumption that the condensate reflects solar abundances, and also the extent of uncertainty in Eq. 1. Nevertheless, we consider that the assumption and the estimation are tolerable for our purpose. Normalization of the total 85%(47%) to 100% yields 20% C, 7.4% N, and 55% water, (22% C, 5.2% N, and 54% water). Since Orguiel(C1) contained about 3% C and 20% water,[9] the postulated condensate could be regarded as a more primitive carbonaceous chondrite than C1. However, such a primitive carbonaceous chondrite has not yet been seen, and would probably not survive in passage to Earth. A more likely solar object for such condensate may be a comet.

There have been few plausible attempts to use experimental data to estimate the content of volatile elements in early condensates in the solar system. Our study here is one attempt to seek those contents with rather simple experiments. Examination of greater numbers of uncontaminated carbonaceous chondrites will allow better definition of the equation and enable more precise prediction of volatile element contents in early solar system condensates.

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