Annals of Glaciology 10 1988

ELEMENTAL AND ISOTOPIC COMPOSITON OF O_2 AND N_2 GASES IN ICE CORES

(Abstract)

by

T.A. Sowers and M.L. Bender

(Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882, U.S.A.)

and

D. Raynaud and C. Lorius

(Laboratoire de Glaciologie et Géophysique de l'Environnement,
B.P. 96, 38402 St Martin d'Hères Cédex, France)

ABSTRACT

A procedure has been developed to extract and measure the relative concentrations of O_2 and $^{15}N^{14}N$, as well as the isotopic abundance of these occluded gases, in ice cores. A wet-extraction procedure is used to extract 99.995% of the gas from the ice. The gas is removed from the extraction vessel by helium cryogenic trapping of all its constituents in a stainless-steel sample tube immersed in liquid helium. The elemental O_2/N_2 ratio is determined by measuring the ratio of masses $^{16}O^{16}O$ (O_2) and $^{15}N^{14}N$ (N_2) simultaneously, using a Finnigan MAT 251 isotope-ratio mass spectrometer. Mass 29 is used because the instrument cannot be configured to measure masses 28 and 32 simultaneously. The $\delta^{18}O$ of O_2 and $\delta^{15}N$ of N_2 are also measured on the same ice sample. The bubble composition is compared to a dry-air standard admitted to the reference side of the inlet system. The notation used to report the O_2/N_2 ratio is the delta notation:

$$\delta(O_2/N_2) = \left[\frac{R(32/29)_{sa}}{R(32/29)_{st}} - 1\right] \times 10^3$$

$$\text{where } R(32/29) = \left[\frac{(\text{conc. of } ^{16}O^{16}O)}{(\text{conc. of } ^{15}N^{14}N)}\right]$$

Applying these methods both to shallow and to deep ice cores will help us to understand global carbon cycling during the period covered by the ice cores. Changes in the distribution of carbon within the biosphere, atmosphere, oceans, and sediments will produce changes in the O_2/N_2 ratio of the recent atmosphere. Thus measurements of the O_2/N_2 ratio in ice will increase our understanding of the distribution of carbon within various reservoirs.

The $\delta^{18}O$ of O_2 in the atmosphere has been shown to be coupled with the $\delta^{18}O$ of the water used during photosynthesis. The $\delta^{18}O_{water}$ of the whole ocean was 1.3‰ heavier during the last glacial maximum, which has been shown to correspond to a 1.3‰ enrichment in the $\delta^{18}O$ of atmospheric O_2 (Bender and others 1985). Thus the measurements of the $\delta^{18}O$ of O_2 in ice will give an insight into the coupling between biological and hydrological cycles. Measurements of the $\delta^{15}N$ of N_2 serve as a fractionation indicator. Any change in the $\delta^{15}N$ must be due to some fractionation process, as $\delta^{15}N$ cannot have changed over the time-scales in question.

To date, we have analyzed recent (approximately 200 years B.P.) bubble samples from Crête, D10 and Byrd Station ice cores. For the $\delta(O_2/N_2)$ analysis, the range of averaged values from each core was from −0.051 to −7.5‰ relative to present-day air. We believe that the large range is due to separation of O_2 relative to N_2, either during bubble close-off or during storage of the collected cores. For $\delta^{18}O$ of the O_2, the average values ranged from +0.37 to +0.71‰. The $\delta^{15}N$ results ranged from +0.18 to +0.33‰. The results indicate that there has been some fractionation of the gases, based on the $\delta^{15}N$ of the N_2 in the bubbles. There is a striking covariance between $\delta^{18}O$ and $\delta^{15}N$. The correlation coefficient r = 0.96. The slope of $\delta^{18}O$ versus $\delta^{15}N$ is 2.2, which is slightly greater than the slope which would be expected if the two isotopes were fractionated in a mass-dependent fashion. Possible explanations for the isotopic fractionation are: (1) the gases were fractionated during close-off in the firn, or (2) the composition of the bubbles has been changed since coring by diffusion through small cracks in the core. Radial sampling of gases in the core is in progress in order to investigate possible gas diffusion from the core during post-coring relaxation of the ice.

REFERENCE

Bender M L, Labeyrie L D, Raynaud D, Lorius C 1985 Isotopic composition of atmospheric O_2 in ice linked with deglaciation and global primary productivity. *Nature* 318(6044): 349-352

https://doi.org/10.3189/S0260305500004651 Published online by Cambridge University Press