# Errata to

# $CO_2$ in Seawater: Equilibrium, Kinetics, Isotopes

**R. E. Zeebe[1] and D. A. Wolf-Gladrow[2]**

[1] Department of Oceanography, University of Hawaii at Manoa,
SOEST, 1000 Pope Road, MSB 504, Honolulu, HI 96822, USA.
zeebe@hawaii.edu
[2] Alfred Wegener Institute for Polar and Marine Research
P.O. Box 12 01 61, D-27515 Bremerhaven, Germany.
dwolf@awi-bremerhaven.de

Elsevier Oceanography Book Series, 65, 2001.
Reprinted in 2003, 2005.

Supplemental MATLAB routines (including *new program file* csys3.m)
are available at:
**www.soest.hawaii.edu/oceanography/faculty_html/zeebe2.html**
**www.awi-bremerhaven.de/Carbon/co2book.html**

March 2, 2010

# Errata I (included in 1st reprint 2003)

p. 19: Replace:
"A doubling of the $Mg^{2+}$ concentration, for example, will reduce $pK_1^*$ from 5.86 to 5.80 and $pK_2^*$ from 8.93 to 8.87."
by
"A doubling of the $Mg^{2+}$ concentration, for example, will reduce $pK_1^*$ from 5.86 to 5.80 and $pK_2^*$ from 8.93 to 8.77."
**(8.87 → 8.77)**.

p. 174, footnote: replace

$$\alpha'_{(CO_2-HCO_3^-)} = \alpha_{(CO_2-HCO_3^-)} \frac{1 - [^{13}CO_2]/[CO_2]}{1 - [H^{13}CO_3^-]/[HCO_3^-]}$$

by

$$\alpha'_{(CO_2-HCO_3^-)} = \frac{1 - [^{13}CO_2]/[CO_2]}{1 - [H^{13}CO_3^-]/[HCO_3^-]}$$

p. 194 Fig. 3.3.19: time is in calender years (not: $^{14}C$ age).

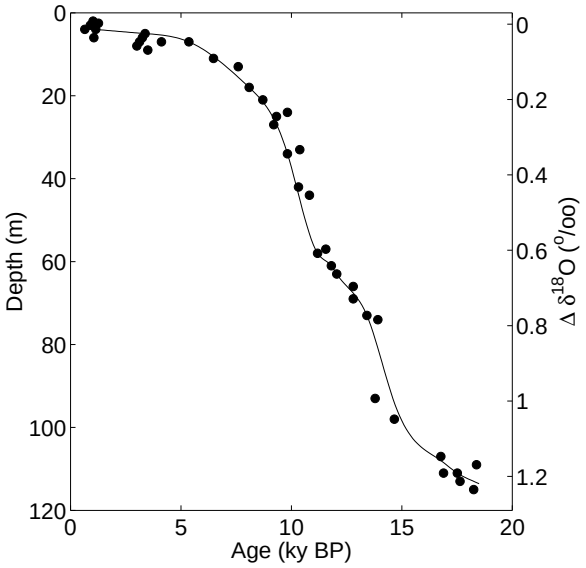


Figure 3.3.19: Sea level curve and seawater $\delta^{18}O$ as derived from Barbados corals for the time period from 18,000 yr B.P. until today (after Fairbanks, 1989).

p. 219: Fig 3.4.30 below was plotted using $pK_B^* = 8.70$ instead of 8.60.

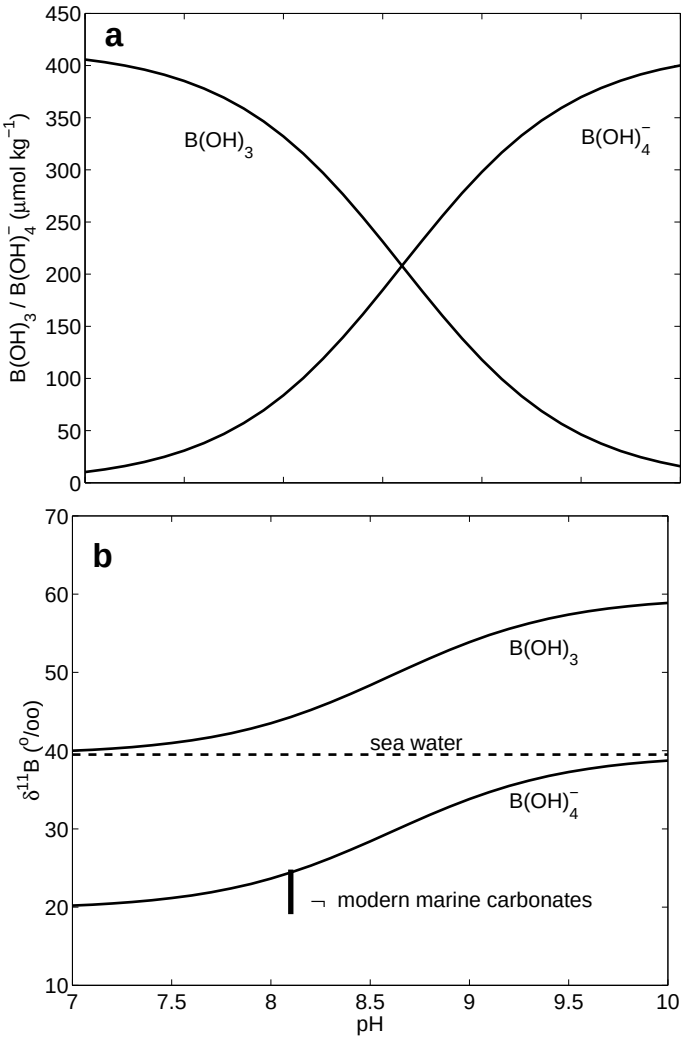


Figure 3.4.30: (a) The concentration of dissolved boron species as a function of $p$H ($T = 25°$C, $S = 35$). The dissociation constant of boric acid $pK_B^*$ is 8.60; the total boron concentration is 416 $\mu$mol kg$^{-1}$ (DOE, 1994). (b) Boron isotopic composition of $B(OH)_3$ and $B(OH)_4^-$ as a function of $p$H (cf. Hemming and Hanson (1992)).

p. 260: Eq. (A.5.9): 0.02824 instead of 0.02924.

p. 261-262: Figures A.5.5 and A.5.6: please note that K values were plotted in the book for hydrogen sulfate and hydrogen fluoride, whereas for all other acids the plots show $p$K values. Plots of $pK_{\mathrm{S}}^{*}$ and $pK_{\mathrm{F}}^{*}$ are provided below.

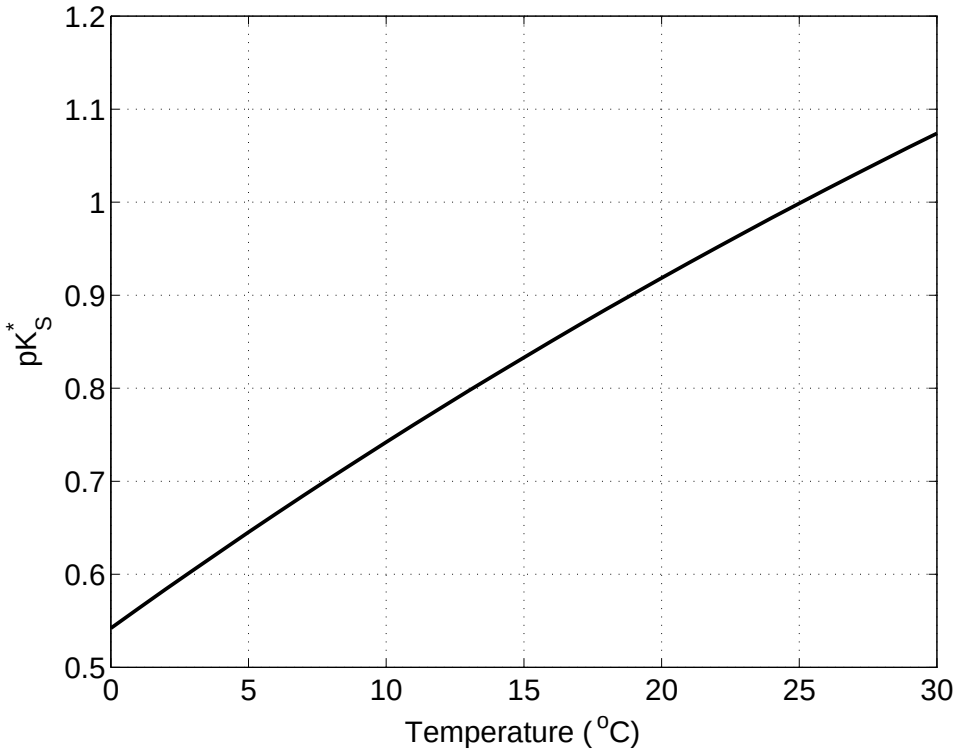


Figure A.5.5: Stability constant of hydrogen sulfate, $pK_{\mathrm{S}}^{*}$, at $S = 35$ as a function of temperature.

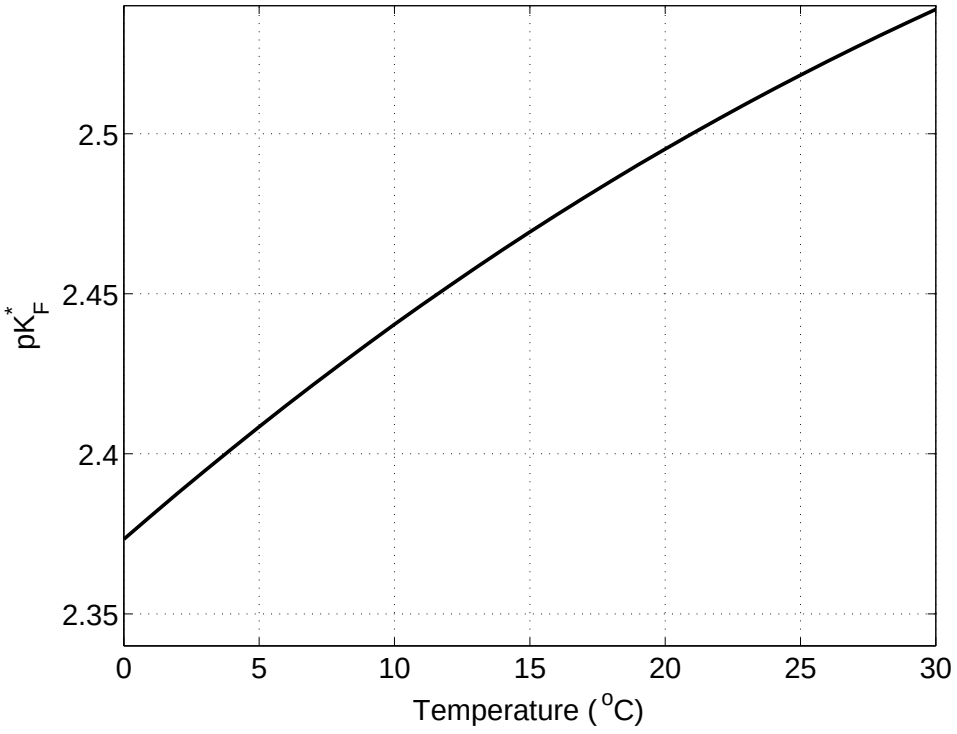


Figure A.5.6: Stability constant of hydrogen fluoride, $pK^*_{\mathrm{F}}$, at $S = 35$ as a function of temperature.

p. 266: the units of $\mathrm{K}^*_{\mathrm{sp}}$(cal) and $\mathrm{K}^*_{\mathrm{sp}}$(arg) should read $\mathrm{mol}^2$ $(\mathrm{kg\text{-}soln})^{-2}$ (not: mol $(\mathrm{kg\text{-}soln})^{-1}$).

## Errata II (included in 2nd reprint 2005)

pp. vii, 53, 251, 269, 271, references to
www.soest.hawaii.edu/oceanography/faculty_html/zeebe2.html added.

p. 67, unit of $K_0$ in Fig. 1.5.20 should be $\mu$mol kg$^{-1}$ $\mu$atm$^{-1}$ (not $\mu$mol $\mu$atm$^{-1}$).

p. 77, replace first part of Eq. (1.6.94) by

$$r = \frac{\gamma}{1-\gamma} \ .$$

p. 239, Replace:
"... $m'$ and $m$ are the masses of $^{16}$O and $^{18}$O ..." by
"... $m'$ and $m$ are the masses of $^{18}$O and $^{16}$O ...".
**(16 $\longleftrightarrow$ 18)**.

p. 244, Replace (below Eq. (3.5.58)):
"... $\omega$ and $\omega'$ are the wavenumbers ..." by
"... $\omega'$ and $\omega$ are the wavenumbers ...".
**($\boldsymbol{\omega \longleftrightarrow \omega'}$)**.

## Errata III (not yet included)

The original description of stable oxygen isotope fractionation in the carbonate system (Chapter 3.3.5 and Appendix C.9) followed Usdowski et al. (1991). This analysis is incorrect and should be replaced by the description presented by Zeebe (2007).

p. 72, Replace Eq. (1.5.88) by:

$$\begin{aligned}
\frac{d\mathrm{DIC}}{ds} &= \left[D_s - D_h A_s A_h^{-1}\right] \\
&= \frac{4\dfrac{K_1^* K_2^*}{h^2} + \dfrac{K_1^*}{h} + \dfrac{(K_1^*)^2 K_2^*}{h^3}}{4\dfrac{K_1^* K_2^*}{h^2} + \dfrac{K_1^*}{h} + \dfrac{h}{s}\left[1 + \dfrac{K_\mathrm{w}^*}{h^2} + \dfrac{B_T K_\mathrm{B}^*}{(K_\mathrm{B}^* + h)^2}\right]} \\
&\quad + \frac{\dfrac{h}{s}\left(1 + \dfrac{K_1^* K_2^*}{h^2} + \dfrac{K_1^*}{h}\right)\left(1 + \dfrac{K_\mathrm{w}^*}{h^2} + \dfrac{B_T K_\mathrm{B}^*}{(K_\mathrm{B}^* + h)^2}\right)}{4\dfrac{K_1^* K_2^*}{h^2} + \dfrac{K_1^*}{h} + \dfrac{h}{s}\left[1 + \dfrac{K_\mathrm{w}^*}{h^2} + \dfrac{B_T K_\mathrm{B}^*}{(K_\mathrm{B}^* + h)^2}\right]} \ .
\end{aligned}$$

p. 267, Table A.11.1. Replace $K_B^*$ coefficient ($10^3 a_2 = 2.6080$) by $-2.6080$.

p. 268, Table A.11.2. Replace $pK_B^*$ check value at $P = 300$ bars (8.4746) by 8.4575.

## Additions

A platform-independent (PC, MAC, Unix) carbon system program can be found under:

`http://www.obs-vlfr.fr/~gattuso/seacarb.php`

p. 50 Figure 1.2.16: for further discussion of normalization by salinity compare Friis et al. (2003).

p. 188: Dole effect: the first paper is by Dole (1935).

p. 310 Table E.0.2: Notation (Latin letters)

$\hbar = 1.054 \times 10^{-34}$ J s is Planck's constant divided by $2\pi$.

# References

DOE. *Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2.* Dickson, A. G. and Goyet, C., editors. ORNL/CDIAC-74, 1994.

Dole, M. The relative atomic weight of oxygen in water and air. *J. Am. Chem. Soc.*, 57:2731ff, 1935.

Fairbanks, R. G. A 17,000-year glacio-eustatic sea level record: Influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. *Nature*, 342:637–642, 1989.

Friis, K., A. Körtzinger, and D. W. R. Wallace. The salinity normalization of marine inorganic carbon chemistry data. *Geophys. Res. Lett.*, 30(2):1085, doi:10.1029/2002GL015898, 2003.

Hemming, N. G. and G. N. Hanson. Boron isotopic composition and concentration in modern marine carbonates. *Geochim. Cosmochim. Acta*, 56:537–543, 1992.

Usdowski, E., J. Michaelis, M. E. Boettcher, and J. Hoefs. Factors for the oxygen isotope equilibrium fractionation between aqueous and gaseous $CO_2$, carbonic acid, bicarbonate, carbonate, and water (19°C). *Z. Phys. Chem.*, 170:237–249, 1991.

Zeebe, R. E. An expression for the overall oxygen isotope fractionation between the sum of dissolved inorganic carbon and water. *Geochem. Geophys. Geosyst.*, 8(9):Q09002, doi:10.1029/2007GC001663, 2007.