Notes on the function gsw_osmotic_pressure_t_exact(SA,t,pw)

This function, **gsw_osmotic_pressure_t_exact**(SA,t,pw) evaluates the osmotic pressure $p^{\mathrm{osm}} = p - p^{\mathrm{W}}$ of seawater from implicitly solving Eqn. (3.41.1) of the TEOS-10 Manual (IOC *et al*., 2010), namely

$$g\left(0, t, p^{\mathrm{W}}\right) = g\left(S_{\mathrm{A}}, t, p\right) - S_{\mathrm{A}} \left.\frac{\partial g}{\partial S_{\mathrm{A}}}\right|_{T,p} . \qquad (3.41.1)$$

This equation represents the osmotic equilibrium, achieved when the chemical potential of pure water at the pressure p^{W} (the left-hand side of this equation) is equal to the chemical potential of water in seawater at the pressure p (the right-hand side of the equation).

This function **gsw_osmotic_pressure_t_exact**(SA,t,pw) uses the full TEOS-10 Gibbs function $g\left(S_{\mathrm{A}}, t, p\right)$ of IOC *et al*. (2010), being the sum of the IAPWS-09 and IAPWS-08 Gibbs functions. Equation. (3.41.1) is solved for p for the given input values of $\left(S_{\mathrm{A}}, t, p^{\mathrm{W}}\right)$ using a modified Newton-Raphson method, and after two iterations of this method, the value of p which satisfies Eqn. (3.41.1) is found to machine precision of $6x10^{-12}$ dbar.

This function **gsw_osmotic_pressure_t_exact**(SA,t,pw) returns the osmotic pressure of seawater, $p^{\mathrm{osm}} = p - p^{\mathrm{W}}$, in units of dbar.

References

IAPWS, 2008: Release on the IAPWS Formulation 2008 for the Thermodynamic Properties of Seawater. The International Association for the Properties of Water and Steam. Berlin, Germany, September 2008, available from www.iapws.org. This Release is referred to in the text as **IAPWS-08**.

IAPWS, 2009: Supplementary Release on a Computationally Efficient Thermodynamic Formulation for Liquid Water for Oceanographic Use. The International Association for the Properties of Water and Steam. Doorwerth, The Netherlands, September 2009, available from http://www.iapws.org. This Release is referred to in the text as **IAPWS-09**.

IOC, SCOR and IAPSO, 2010: *The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties*. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, UNESCO (English), 196 pp. Available from http://www.TEOS-10.org

Here follows section 3.41 of the TEOS-10 Manual (IOC *et al*., 2010)).

3.41 Osmotic pressure

If pure water is separated from seawater by a semi-permeable membrane which allows water molecules to pass but not salt particles, water will penetrate into the seawater, thus diluting it and possibly increasing its pressure, until the chemical potential of water in both boxes becomes the same (or the pure water reservoir is exhausted). In the usual model configuration, the two samples are thermally coupled but may possess different pressures; the resulting pressure difference required to maintain equilibrium is the osmotic pressure of seawater. An example of a practical application is desalination by reverse osmosis; if the pressure on seawater in a vessel exceeds its osmotic pressure, freshwater can be "squeezed" out of solution through suitable membrane walls (Sherwood *et al.* (1967)). The osmotic pressure of seawater is very important for marine

organisms; it is considered responsible for the small number of species that can survive in brackish environments.

The defining condition for the osmotic equilibrium is equality of the chemical potentials of pure water at pressure p^{W} and of water in seawater at the pressure p,

$$g\left(0, t, p^{\mathrm{W}}\right) = g\left(S_{\mathrm{A}}, t, p\right) - S_{\mathrm{A}} \left.\frac{\partial g}{\partial S_{\mathrm{A}}}\right|_{T,\,p} . \tag{3.41.1}$$

The solution of this implicit relation for p (given values of S_{A}, t and p^{W}) leads to the osmotic pressure p^{osm}

$$p^{\mathrm{osm}} = p - p^{\mathrm{W}} . \tag{3.41.2}$$

An example of the TEOS-10 value for the osmotic pressure of standard seawater is $p^{\mathrm{osm}}\left(S_{\mathrm{A}} = S_{\mathrm{SO}},\, t = 0\,^{\circ}\mathrm{C},\, p^{\mathrm{W}} = 0\,\mathrm{dbar}\right) = 235.4684$ dbar. Osmotic pressure may be calculated using the **gsw_osmotic_pressure_t_exact**(SA,t,pw) function of the GSW Oceanographic Toolbox.