

# Package ‘marelac’

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**Title** Tools for Aquatic Sciences

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**Depends** R (>= 3.2), shape

**Imports** stats, seacarb

**Description** Datasets, constants, conversion factors, and utilities for 'MArine', 'Riverine', 'Estuarine', 'LAcustrine' and 'Coastal' science.  
The package contains among others: (1) chemical and physical constants and datasets, e.g. atomic weights, gas constants, the earths bathymetry; (2) conversion factors (e.g. gram to mol to liter, barometric units, temperature, salinity); (3) physical functions, e.g. to estimate concentrations of conservative substances, gas transfer and diffusion coefficients, the Coriolis force and gravity; (4) thermophysical properties of the seawater, as from the UNESCO polynomial or from the more recent derivation based on a Gibbs function.

**License** GPL (>= 2)

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## Description

R-package *marelac* has been designed as a tool for use by scientists working in the MARine, Riverine, Estuarine, LAcustrine and Coastal sciences.

It contains:

- chemical and physical constants, e.g. atomic weights, gas constants.
- conversion factors, e.g. from salinity to chlorinity, from mol to gram, etc.,
- utility functions, e.g. to estimate concentrations of conservative substances as a function of salinity, ...

About the symbols used.

Here we adopt the symbolism as in McDougall et al., 2009:

- S for practical (-) or absolute salinity, (g/kg)
- P for absolute (total) pressure (bar)
- p for sea pressure (also called gauge or applied pressure (bar), the pressure relative to P<sub>0</sub>, one standard atmosphere (=1.01325 bar)
- t for temperature in °C
- T for absolute temperature, in °K;  $T = t + 273.15$

Many of the functions are from the UNESCO 1983 paper, or from Feistel, 2008. Note that in these papers, pressure is expressed in dbar.

## Author(s)

Karline Soetaert (Maintainer)

Thomas Petzoldt

with contributions from Lorenz Meire and Filip Meysman

## References

For solubilities, atmospheric composition, gas exchange coefficients:

Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 85.

For diffusion coefficients, viscosity

Boudreau BP, 1996. A method-of-lines code for carbon and nutrient diagenesis in aquatic sediments. Computers & Geosciences 22 (5), 479-496.

For many other fundamental properties of seawater, either the UNESCO report (1983):

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.

<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

or the more recent report and papers:

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. Deep-Sea Research I, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

Millero FJ, Feistel R, Wright DG, and McDougall TJ, 2008. The composition of Standard Seawater and the definition of the Reference-Composition Salinity Scale, Deep-Sea Res. I, 55, 50-72.

## See Also

for seawater properties:

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

for atmospheric gasses:

[gas\\_satconc](#), [gas\\_O2sat](#), [gas\\_schmidt](#), [gas\\_solubility](#), [gas\\_transfer](#), [atmComp](#), [vapor](#), [air\\_spechum](#), [air\\_density](#)

conversions:

[convert\\_AStoPS](#), [convert\\_PStoAS](#), [convert\\_RtoS](#), [convert\\_StoCl](#), [convert\\_StoR](#), [convert\\_p](#), [convert\\_T](#)

datasets:

[AtomicWeight](#), [Bathymetry](#), [Constants](#), [Oceans](#)

physical properties:

[earth\\_surf](#), [coriolis](#), [viscosity](#), [diffcoeff](#), [ssd2rad](#), [vertmean](#), [gravity](#)

molecular properties:

[AtomicWeight](#), [molvol](#), [molweight](#), [redfield](#)

**Examples**

```
## Not run:
## show examples (see respective help pages for details)
example(Constants)
example(molvoll)

## open the directory with documents
browseURL(paste(system.file(package="marelac"), "/doc", sep=""))

## End(Not run)
```

---

air_density	<i>Air Density</i>
-------------	--------------------

---

**Description**

The density of the air, in kg/m<sup>3</sup>

**Usage**

```
air_density(t = 25, P = 1.013253)
```

**Arguments**

t	Temperature, °C.
P	True pressure, bar

**Value**

The air density, in kg/m<sup>3</sup>

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>, Lorenz Meire <lorenz.meire@nioz.nl>

**References**

<http://www.cactus2000.de/uk/unit/masshum.shtml>

**See Also**

[vapor](#), [air\\_spechum](#), [gas\\_O2sat](#), [gas\\_satconc](#), [gas\\_schmidt](#), [gas\\_solubility](#), [gas\\_transfer](#), [atmComp](#)

**Examples**

```
air_density(t = 25) # 1.183894
plot(0:30, air_density(t = 0:30), xlab = "Temperature, dgC", ylab = "kg/m3")
plot(x= seq(0.8,1.2, 0.01), y = air_density(P = seq(0.8,1.2, 0.01)),
     xlab = "pressure, bar", ylab = "kg/m3")
```

---

air_spechum	<i>Air specific humidity</i>
-------------	------------------------------

---

**Description**

The specific humidity of air (mass mixing ratio in wet air), in kg/kg

**Usage**

```
air_spechum(t = 25, rh = 50, P = 1.013253)
```

**Arguments**

t	Temperature, °C.
rh	Relative humidity, %
P	True pressure, bar

**Value**

The specific humidity, in kg/kg.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>, Lorenz Meire <lorenz.meire@nioz.nl>

**References**

Lowe, P.R. and J.M. Ficke, 1974: The computation of saturation vapor pressure. Tech. Paper No. 4-74, Environmental Prediction Research Facility, Naval Postgraduate School, Monterey, CA, 27 pp.

<http://www.cactus2000.de/uk/unit/masshum.shtml>

**See Also**

[vapor](#), [air\\_density](#), [gas\\_O2sat](#), [gas\\_satconc](#), [gas\\_schmidt](#), [gas\\_solubility](#), [gas\\_transfer](#), [atmComp](#)

**Examples**

```
air_spechum(t = 25, rh = 50)*1000 # 9.7778
plot(0:30, air_spechum(t = 0:30), xlab = "Temperature, dgC", ylab = "kg/kg")
plot(0:100, air_spechum(rh = 0:100), xlab = "percent humidity", ylab = "kg/kg")
```

**Description**

Provides the global average atmospheric composition at present day conditions (year 1998). The mixing ratio is generally defined as the ratio of the mass of an atmospheric constituent to the total mass of dry air. If not otherwise indicated, the term mixing ratio normally refers to water vapor. Here however the mixing ratio is provided for all constituents other than water. The mixing ratio is given as a mole fraction, i.e. the mass of each constituent gas (expressed in moles) divided by the total mass of dry air (also expressed in moles).

**Usage**

```
atmComp(species = c("He", "Ne", "N2", "O2", "Ar", "Kr", "CH4", "CO2",  
"N2O", "H2", "Xe", "CO", "O3"))
```

**Arguments**

species            character vector selecting the gases whose composition should be provided.

**Value**

A vector providing the mixing ratio of the selected gases.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>, Filip Meysman <filip.meysman@nioz.nl>

**References**

Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 85.

They cite Weast and Astle (1982) for all gasses except CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. For the latter three greenhouse gases, the 1998 concentrations are taken from Ramaswamy et al., 2001. Note that the sum of all mixing ratios is slightly larger than one, presumably due to the use of increased greenhouse gases values as compared to Weast and Astle (1982). In fact, the mixing ratio are changing slightly each year due to increases in greenhouse gas concentrations.

**See Also**

[gas\\_02sat](#), [gas\\_satconc](#), [gas\\_schmidt](#), [gas\\_solubility](#), [gas\\_transfer](#), [vapor](#)

**Examples**

```
atmComp("O2")  
atmComp(c("O2", "CH4", "CO2", "N2O"))  
atmComp()  
sum(atmComp()) # note this is not =1!
```

---

AtomicWeight

*The Atomic Weights of Chemical Elements*

---

### Description

Atomic weights of chemical elements according to the IUPAC table.

### Usage

AtomicWeight  
atomicweight

### Format

The capitalized version AtomicWeight is a data frame containing the IUPAC table of atomic weights. This data frame has following columns: Number, Name, Symbol, Weight, Footnotes.

Note that as in the IUPAC table, the Weight is given as a text rather than as numeric objects. It comprises the standard values and the uncertainties (in parentheses, following the last significant figure to which they are attributed). See IUPAC report for explanation of the Footnotes.

The lower case version atomicweight is a simplified list that only contains the weights (as numeric values) and allows symbolic computations with elements to arrive at molecular weights.

### Details

Molecular weights of chemical elements may vary due to different isotope compositions, depending on geology, industrial processes or biological activity. Please consult the IUPAC Technical report about the details. The data set contains NA for elements that have no stable isotopes (except U, Th, Pa).

### Author(s)

Thomas Petzoldt

### References

Wieser ME, 2006. Atomic weights of the elements 2005 (IUPAC Technical Report). Pure Appl. Chem. 78 (11), 2051–2066., 2006. DOI: 10.1351/pac200678112051

### See Also

other datasets: [Bathymetry](#), [Constants](#), [Oceans](#),  
[molweight](#) for molecular weight calculations with molecular formulae.



**Examples**

```
## assess the data in the IUPAC table (with all footnotes)
AtomicWeight[1:20,]
AtomicWeight[AtomicWeight$Symbol == "C",]

## use the lower case version for simple calculations:
atomicweight$C
with(atomicweight, C)

## it can also be used to calculate molecular weights
## via symbolic computation
with(atomicweight, H * 2 + O)
```

---

Bathymetry

*World Bathymetric Data*

---

**Description**

This dataset contains the elevation of sea (bathymetry) and land (hypsometry) across the globe at 1 degree intervals. Dataset as used by Andersson et al. (2004).

**Usage**

Bathymetry

**Format**

A list with the bathymetry (depth) and hypsometry (altitude) of the world. It contains:

**x** the latitude,  
**y** the longitude,  
**z** the height (m).

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Andersson H, Wijsman J, Herman PMJ, Middelburg J, Soetaert K and Heip C, 2004. Respiration patterns in the deep ocean. *Geophysical Research Letters* 31, LO3304.

**Examples**

```

par(mar = c(2,2,2,2))
image(Bathymetry$x, Bathymetry$y, Bathymetry$z, col = femmecol(100),
      asp = TRUE, xlab = "dg", ylab = "dg")
contour(Bathymetry$x, Bathymetry$y, Bathymetry$z, asp = TRUE, add = TRUE)

# remove land
zz      <- Bathymetry$z
zz[zz>0] <- 0

image(Bathymetry$x, Bathymetry$y, zz, col = c(femmecol(100), "black"),
      asp = TRUE)
contour(Bathymetry$x, Bathymetry$y, zz, asp = TRUE, add = TRUE)

```

---

 Constants

*Useful Physical and Chemical Constants*


---

**Description**

Physical and chemical constants useful for aquatic sciences.

**Usage**

Constants

**Format**

A list specifying the value, the units, and a description for each physical constant.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Mohr PJ and Taylor BN, 2005. CODATA recommended values of the fundamental physical constants: 2002, *Review of Modern Physics* 77, 1 - 107.

**See Also**

[AtomicWeight](#), [Bathymetry](#), [Oceans](#)

**Examples**

```

data.frame(cbind(acronym = names(Constants),
                 matrix(ncol = 3, byrow = TRUE, data = unlist(Constants),
                       dimnames = list(NULL, c("value", "units", "description")))))

```

---

`convert_p`*Conversion Between Different Barometric Units*

---

**Description**

The function converts between different units of pressure.

**Usage**

```
convert_p(x, unit = c("Pa", "bar", "at", "atm", "torr"))
```

**Arguments**

`x` vector of given pressure values,  
`unit` measurement unit of the given value(s).

**Value**

A data frame with converted values.

**References**

[http://en.wikipedia.org/wiki/Bar\\_\(unit\)](http://en.wikipedia.org/wiki/Bar_(unit))

**See Also**

[convert\\_AStoPS](#), [convert\\_PStoAS](#), [convert\\_RtoS](#), [convert\\_StoCl](#), [convert\\_StoR](#), [convert\\_T](#),

**Examples**

```
convert_p(1, "atm")  
convert_p(c(2, 3, 4.5), "bar")  
  
convert_p(1, "atm")$Pa
```

---

`convert_RtoS`*Conductivity-Salinity Conversion*

---

**Description**

Estimates the salinity of seawater from conductivity, temperature and pressure. The equation is valid over ranges: temperature from -2 to 35 °C, pressure from 0 to 1000 bar, and salinity from 2 to 42.

**Usage**

```
convert_RtoS(R = 1, t = 25, p = max(0, P-1.013253), P = 1.013253)
```

**Arguments**

R	Conductivity ratio, the conductivity at (S, t, P) divided by the conductivity at S = 35, t = 15, p = 0 [-]
t	Temperature, °C
p	Gauge (or applied) pressure, the pressure referenced against the local atmospheric pressure, bar
P	True pressure, bar

**Value**

The salinity.

**Note**

The conductivity ratio for Salinity = 40.0000, t = 40, p = 1000 is 1.888091.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.  
<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

**See Also**

[convert\\_AStoPS](#), [convert\\_PStoAS](#), [convert\\_StoR](#), [convert\\_StoCl](#), [convert\\_p](#), [convert\\_T](#),

**Examples**

```
convert_RtoS(R = 1.888091, t = 40, p = 1000)

## Salinity = 40.0000, t = 40, p = 1000, cond = 1.888091
convert_RtoS(R = 1, t = 15, p = 0)

## Check values
convert_RtoS(R = 0.6990725, t = 10, p = 0) # 26.8609
convert_RtoS(R = 0.6990725, t = 10, p = 100) # 26.5072
convert_RtoS(R = 1.1651206, t = 20, p = 100) # 36.3576
```

---

convert\_salinity      *Practical - Absolute Salinity Conversions*

---

### Description

Conversion from practical to absolute salinity and vice versa.

### Usage

```
convert_PStoAS(S = 35, p = max(0, P - 1.013253), P = 1.013253,
  lat = NULL, lon = NULL, DSi = NULL,
  Ocean = c("Global", "Atlantic", "Pacific", "Indian", "Southern"))
```

```
convert_AStoPS(S = 35, p = max(0, P - 1.013253), P = 1.013253,
  lat = NULL, lon = NULL, DSi = NULL,
  Ocean = c("Global", "Atlantic", "Pacific", "Indian", "Southern"))
```

### Arguments

S	Salinity, either practical salinity (convert_PStoAS), dimensionless or absolute salinity (convert_AStoPS, g/kg)
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar
lat	latitude (-90 to +90)
lon	longitude (0 to 360)
DSi	the silicate concentration, in micromol/kg
Ocean	the ocean in which the measurement was taken; only used if DSi is not NULL

### Details

Absolute salinity (g kg<sup>-1</sup>) is estimated from Practical salinity as:

$$AS = 35.16504 / 35 * PS + \text{delt}()$$

where delt is the absolute salinity anomaly. There are two ways in which to estimate the salinity anomaly

1. If DSi is not given a value, then the anomaly is estimated as a function of longitude lon, latitude lat and pressure p, using the lookup table as in sw\_sfac.
2. If DSi is given a value, then a regression on it is used, based on the values of Ocean and -except for the "global" ocean- the latitude lat:

**"Global"** a global estimate is used,

$$\text{delt} = 9.824e-5 * DSi,$$

```

"Southern" the Southern Ocean (lat < -30),
  delt= 7.4884e-5 *DSi,
"Pacific" the Pacific Ocean ,
  delt= 7.4884e-5 *(1 + 0.3622[lat/30 + 1])*DSi,
"Indian" the Indian Ocean ,
  delt= 7.4884e-5 *(1 + 0.3861[lat/30 + 1])*DSi,
"Atlantic" the Atlantic Ocean ,
  delt= 7.4884e-5 *(1 + 1.0028[lat/30 + 1])*DSi,

```

Note that for the Pacific, Indian and Atlantic Ocean regression, the latitude is needed. If lat is NULL then the Global regression will be used.

### Value

The absolute salinity (convert\_PStoAS) or practical salinity (convert\_AStoPS).

### Author(s)

Karline Soetaert <karline.soetaert@nioz.nl>

### References

Millero FJ, Feistel R, Wright DG and McDougall TJ, 2008. The composition of Standard Seawater and the definition of the Reference-Composition Salinity Scale, Deep-Sea Res. I, 55, 50-72.

McDougall TJ, Jackett DR and Millero FJ, 2009. An algorithm for estimating Absolute Salinity in the global ocean. Ocean Science Discussions 6, 215-242. <http://www.ocean-sci-discuss.net/6/215/2009/>

Uses the Fortran code written by David Jackett. <http://www.marine.csiro.au/~jackett/TEOS-10/>

### See Also

[convert\\_RtoS](#), [convert\\_StoR](#), [convert\\_StoCl](#), [convert\\_p](#), [convert\\_T](#),

### Examples

```

# check values: should be 35.7
convert_PStoAS(S = 35.52764437773386, p = 102.3, lon = 201, lat = -21)

# check values: should be 35.52764437773386
convert_AStoPS(S = 35.7, p = 102.3, lon = 201, lat = -21)

#
convert_PStoAS(S = 35)
convert_AStoPS(S = 35)
convert_PStoAS(S = 35, lat = 10, lon = 10, p = 0)

# Based on Si concentration
DSi <- seq(from = 0, to = 200, by = 10)
Global <- convert_PStoAS(30, DSi = DSi, Ocean = "Global")

```

```
Atlantic <- convert_PStoAS(30, DSi = DSi, Ocean = "Atlantic", lat = 0)
Pacific <- convert_PStoAS(30, DSi = DSi, Ocean = "Pacific", lat = 0)
Indian <- convert_PStoAS(30, DSi = DSi, Ocean = "Indian", lat = 0)
Southern <- convert_PStoAS(30, DSi = DSi, Ocean = "Southern")

matplot(x = DSi, y = cbind(Global, Atlantic, Pacific, Indian, Southern),
  pch = 1, xlab = "DSi, micromol/kg", ylab = "Absolute salinity (PS=30)")
legend("topleft",c("Global", "Atlantic", "Pacific", "Indian", "Southern"),
  col = 1:5, pch = 1)
```

---

convert\_StoCl

*Salinity-Chlorinity Conversion*

---

### Description

Estimates the chlorinity concentration based on salinity

### Usage

```
convert_StoCl(S = 35)
```

### Arguments

S                    salinity

### Value

The chlorinity concentration, g/kg

### Author(s)

Karline Soetaert <karline.soetaert@nioz.nl>

### References

Cox RA, Culkin F, Riley JP, 1967. The electrical conductivity – chlorinity relationship in natural seawater. Deep-Sea Research 14, 203–220.

### See Also

[convert\\_AStoPS](#), [convert\\_PStoAS](#), [convert\\_RtoS](#), [convert\\_StoR](#), [convert\\_p](#), [convert\\_T](#),

### Examples

```
convert_StoCl(20)
```

---

 convert\_StoR

*Salinity-Conductivity Conversion*


---

**Description**

Estimates the conductivity ratio from salinity, temperature and pressure.

The equation is valid over ranges of temperature from -2 to 35 °C, pressure of 0 - 1000 bar and salinity 2-42 in the world ocean.

**Usage**

```
convert_StoR(S = 35, t = 25, p = max(0, P-1.013253), P = 1.013253)
```

**Arguments**

S	(practical) Salinity, -,
t	Temperature, °C,
P	True Pressure, bar,
p	Gauge (or applied) pressure, the pressure referenced against the local atmospheric pressure, bar.

**Value**

The conductivity ratio (-), this is the conductivity at (S, t, p), divided by the conductivity at S = 35, t = 15, p = 0.

**Note**

Pressure here is true pressure, 1 bar (at sea surface), in contrast to hydrostatic pressure in dbar of original formula.

The conductivity ratio for Salinity = 40, t = 40, p = 1000 is 1.888091.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.

<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

**See Also**

[convert\\_AStoPS](#), [convert\\_PStoAS](#), [convert\\_RtoS](#), [convert\\_StoCl](#), [convert\\_p](#), [convert\\_T](#),



**Examples**

```

convert_StoR(S = 40, t = 40, p = 1000)

convert_StoR(S = 35, t = 15, p = 0)

# Check values:
convert_StoR(S = 25, t = 10, p = 0) # 0.654990
convert_StoR(S = 25, t = 10, p = 100) # 0.662975
convert_StoR(S = 25, t = 10, p = 1000) # 0.712912

convert_StoR(S = 35, t = 10, p = 100) # 0.897778
convert_StoR(S = 40, t = 10, p = 100) # 1.011334

```

---

 convert\_T

*Conversion Between Different Temperature Units*


---

**Description**

The function converts between different units of temperature.

**Usage**

```
convert_T(x, unit = c("K", "C", "F"))
```

**Arguments**

x	Vector of given temperature values,
unit	Measurement unit of the given value(s).

**Value**

A data frame with converted values.

**References**

Mangum BW and Furukawa GT, 1990. Guidelines for Realizing the International Temperature Scale of 1990 (ITS-90). NIST Technical Note 1265. and the url

<http://www.cstl.nist.gov/div836/836.05/papers/magnum90ITS90guide.pdf>

**See Also**

[convert\\_AStoPS](#), [convert\\_PStoAS](#), [convert\\_RtoS](#), [convert\\_StoR](#), [convert\\_StoCl](#), [convert\\_p](#)

**Examples**

```

convert_T(0, "K")
convert_T(0, "C")
convert_T(0, "F")

convert_T(273.15, "K")
convert_T(-273.15, "C")
convert_T(c(-459.67, 0, 32), "F")

convert_T(32, "F")$C # 0 degrees C

```

---

coriolis

*The Coriolis Force as a Function of Latitude*


---

**Description**

Estimates the coriolis factor,  $f$  (in  $s^{-1}$ ), where  $f = 2 \cdot \omega \cdot \sin(lat)$ , where  $\omega = 7.292e^{-5}$  radians/sec, the rotation of the earth.

**Usage**

```
coriolis(lat)
```

**Arguments**

lat                    latitude in degrees north (-90 to +90).

**Value**

The coriolis factor ( $s^{-1}$ ).

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl >

**References**

Pond S and Pickard G, 1986. Introductory Dynamical Oceanography, Pergamon Press, Sydney, 2nd Ed.

Griffies SM, 2004. Fundamentals of Ocean Climate Models. Princeton, NJ, Princeton University Press, 518 pp.

**See Also**

[viscosity](#), [diffcoeff](#), [ssd2rad](#), [vertmean](#), [gravity](#)

**Examples**

```
plot(-90:90, coriolis(-90:90), xlab = "latitude, dg North",
     ylab = "/s", main = "coriolis factor", type = "l", lwd = 2)
```

diffcoeff

*Molecular Diffusion Coefficients***Description**

Calculates the molecular and ionic diffusion coefficients in  $m^2 s^{-1}$ , for several inorganic species in seawater at a given salinity, temperature, and pressure.

Based on Chapter 4 in Boudreau (1997)

**Usage**

```
diffcoeff(S = 35, t = 25, P = 1.013253,
  species = c("H2O", "O2", "CO2", "H2", "CH4", "DMS",
    "He", "Ne", "Ar", "Kr", "Xe", "Rn",
    "N2", "H2S", "NH3", "NO", "N2O", "CO", "SO2",
    "OH", "F", "Cl", "Br", "I",
    "HCO3", "CO3", "H2PO4", "HPO4", "PO4",
    "HS", "HSO3", "SO3", "HSO4", "SO4", "IO3", "NO2", "NO3",
    "H", "Li", "Na", "K", "Cs", "Ag", "NH4",
    "Ca", "Mg", "Fe", "Mn", "Ba", "Be", "Cd", "Co",
    "Cu", "Hg", "Ni", "Sr", "Pb", "Ra", "Zn", "Al", "Ce",
    "La", "Pu", "H3PO4", "BOH3", "BOH4", "H4SiO4"))
```

**Arguments**

S	Salinity, -,
t	Temperature, °C,
P	True pressure, bar,
species	character vector with the names of the chemical species whose diffusion coefficient should be calculated.

**Details**

To correct for salinity, the Stokes-Einstein relationship is used. This is not quite accurate, but is at least consistent.

$H_3PO_4$  : Least (1984) determined  $D(H_3PO_4)$  at 25 deg C and 0 S. Assume that this value can be scaled by the Stokes-Einstein relationship to any other temperature.

$B(OH)_3$  : Mackin (1986) determined  $D(B(OH)_3)$  at 25 deg C and about 29.2 S. Assume that this value can be scaled by the Stokes-Einstein relationship to any other temperature.

$B(OH)_4$  : No information on this species. Boudreau and Canfield (1988) assume it is 12.5% smaller than  $B(OH)_3$ .

$H_4SiO_4$  : Wollast and Garrels (1971) found  $D(H_4SiO_4)$  at 25 deg C and 36.1 ppt S. Assume that this value can be scaled by the Stokes-Einstein relationship to any other temperature.

Arguments salinity, temperature or pressure can be vectors. In order to avoid confusion, S, t and P must have either same length or length 1. More flexible combinations are of course possible with [expand.grid](#)

### Value

A data.frame with the diffusion coefficients  $m^2s^{-1}$  of the selected chemical species.

### Author(s)

Filip Meysman <filip.meysman@nioz.nl>, Karline Soetaert <karline.soetaert@nioz.nl>

### References

Based on Chapter 4 in Boudreau (1997) :

Boudreau BP, 1997. Diagenetic Models and their Implementation. Modelling Transport and Reactions in Aquatic Sediments. Springer. Berlin.

who cites:

for self-diffusion coefficient H<sub>2</sub>O:

Cohen MH and Turnbull D. 1959. Molecular transport in liquids and glasses. Journal of chemical physics 31 (5): 1164-1169

Krynicky K, Green CD and Sawyer DW, 1978. Pressure and temperature-dependence of self-diffusion in water. Faraday discussions 66: 199-208

for gases O<sub>2</sub> and CO<sub>2</sub>:

Novel relation by Boudreau (1997) based on new compilation of data

for gases He, Ne, Kr, Xe, Rn, H<sub>2</sub>, CH<sub>4</sub>:

Jahne B, Heinz G, and Dietrich W, 1987. Measurements of the diffusion coefficients of sparingly soluble gases in water. J. Geophys. Res., 92:10,767-10,776.

for Ar:

Ohsumi T and Horibe Y, 1984. Diffusivity of He and Ar in deep-sea sediments, Earth and Planetary Science Letters 70, 61-68.

for DMS:

Saltzman ES, King DB, Holmen K, and Leck C, 1993. Experimental Determination of the Diffusion Coefficient of Dimethylsulfide in Water, J. Geophys. Res., 98(C9), 16, 481-486.

for other gases (N<sub>2</sub>, H<sub>2</sub>S, NH<sub>3</sub>, NO, N<sub>2</sub>O, CO, SO<sub>2</sub>):

Wilke CR and Chang P, 1955. Correlation of diffusion coefficients in dilute solutions. Aiche journal 1 (2): 264-270

with the correction proposed by

Hayduk W and Laudie H, 1974. Prediction of diffusion-coefficients for nonelectrolytes in dilute aqueous-solutions. Aiche journal 20 (3): 611-615

for ions:

Hayduk W and Laudie H, 1974. Prediction of diffusion-coefficients for nonelectrolytes in dilute aqueous-solutions. Aiche journal 20 (3): 611-615

for H3PO4, B(OH)3, B(OH)4, H4SiO4 : see details

### See Also

[coriolis](#), [viscosity](#), [ssd2rad](#), [vertmean](#), [gravity](#)

### Examples

```
diffcoeff(S = 15, t = 15)*1e4*3600*24      # cm2/day
diffcoeff(t = 10, species = "O2")        # m2/s
difftemp <- diffcoeff(t = 0:30)[,1:13]
matplot(0:30, difftemp, xlab = "temperature", ylab = "m2/s",
        main = "Molecular/ionic diffusion", type = "l",
        col = 1:13, lty = 1:13)
legend("topleft", ncol = 2, cex = 0.8, title = "mean",
       col = 1:13, lty = 1:13,
       legend = cbind(names(difftemp),
                       format(colMeans(difftemp), digits = 4)))

## vector-valued salinity
select <- c("O2", "CO2", "NH3", "NH4", "NO3")
diffsal <- diffcoeff(S = 0:35, species = select)
matplot(0:35, diffsal, xlab = "salinity", ylab = "m2/s",
        main = "Molecular/ionic diffusion", type = "l",
        col = 1:length(select), lty = 1:length(select))
legend("topleft", ncol = 2, cex = 0.8, title = "mean",
       col = 1:length(select), lty = 1:length(select),
       legend = cbind(select, format(colMeans(diffsal), digits = 4)))

## vector-valued temperature
difftemp <- diffcoeff(S = 1, t=1:20, species = select)
matplot(1:20, difftemp, xlab = "temperature", ylab = "m2/s",
        main = "Molecular/ionic diffusion", type = "l",
        col = 1:length(select), lty = 1:length(select))
legend("topleft", ncol = 2, cex = 0.8, title = "mean",
       col = 1:length(select), lty = 1:length(select),
       legend = cbind(select, format(colMeans(difftemp), digits = 4)))

## combination of S and t
differaltemp <- diffcoeff(S = rep(c(1, 35), each = 20),
                          t = rep(1:20, 2), species = select)
```

**Description**

earth\_surf computes the surface of 1d by 1dg grid cells as a function of latitude.

Based on data that give the surface distance per 1 dg change in lat/lon from <http://en.wikipedia.org/wiki/Latitude>

earth\_dist calculates the distance between two (lat, lon) points

**Usage**

```
earth_surf(lat = 0, lon = 0)
earth_dist(alat, alon, blat, blon, method = 1)
```

**Arguments**

lat	latitude (-90 - +90).
lon	longitude - not used.
alat	first latitude (-90 - +90).
alon	first longitude (-180, 180).
blat	second latitude (-90 - +90).
blon	second longitude (-180, 180).
method	an integer indicating the formula to use, either the spherical law of cosines (1) or the haversine formula (2)

**Value**

Surface of the grid cell, in  $m^2$ .

Distance between the points (alat, alon), (blat, blon), m.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**See Also**

[Bathymetry, Oceans](#)

**Examples**

```
earth_surf(seq(0, 90, by = 15))

SURF <- outer(X = Bathymetry$x,
              Y = Bathymetry$y,
              FUN <- function(X, Y) earth_surf(Y, X))

earth_dist(10, 80, 10, 81)
earth_dist(20, 80, 20, 81)
```

```

SURF <- outer(X = Bathymetry$x,
              Y = Bathymetry$y,
              FUN <- function(X, Y) earth_surf(Y, X))

sum(SURF)                                #is: 510,072,000 km2

# the surface of the Oceans, m2
sum(SURF*(Bathymetry$z < 0))              # is: 3.58e14

# the volume of the Oceans, m3
- sum(SURF*Bathymetry$z*(Bathymetry$z < 0)) # is: 1.34e+18

# the surface area at several depths
SurfDepth <- vector()

dseq <- seq(-7500, -250, by = 250)

for (i in 2:length(dseq)) {
  ii <- which (Bathymetry$z > dseq[i-1] & Bathymetry$z <= dseq[i])
  SurfDepth[i-1]<-sum(SURF[ii])
}

plot(dseq[-1], SurfDepth, xlab = "depth, m", log = "y",
      ylab = "m2", main = "Surface at ocean depths")

```

---

gas\_02sat

*Saturation Concentration of Oxygen in Water*


---

### Description

Empirical formulae that can be used to compute saturation concentration of oxygen in water in *mg/L*

### Usage

```
gas_02sat(S = 35, t = 25, masl = 0, method = c("Weiss", "APHA", "Paul"))
```

### Arguments

S	salinity (dimensionless, for method "Weiss" only),
t	Temperature in °C,
masl	height above sea level (in m, for method "Paul" only),
method	formula to be used, see references for correct application.

## Details

Method APHA is the standard formula in Limnology, method Weiss the standard formula in marine sciences. The method after Paul is a simple formula fitted on available tables. To avoid confusion between the arguments (S, t, masl) it is advisable to use named arguments in general, e.g. O2sat (t = 4).

## Value

Vector with oxygen saturation concentration in  $mgL^{-1}$ .

## References

American Public Health Association, Inc. (1985): Standard Methods for the Examination of Water and Wastewater. 18th edition, 1992.

Benson BB and Krause D, 1980. The concentration and isotopic fractionation of gases dissolved in freshwater in equilibrium with the atmosphere. I. Oxygen. *Limnology and Oceanography* 25, 662-671.

Brown LC and Barnwell TO Jr, 1987. The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual. U.S. Environmental Protection Agency, Athens, Georgia. EPA/600/3-87/007, p. 41. <http://www.epa.gov>

DIN 38408-23, Ausgabe:1987-11: Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung; Gasförmige Bestandteile (Gruppe G); Bestimmung des Sauerstoffsättigungsindex (G 23).

Paul L, 1985. Das thermische Regime der Talsperre Saldenbach und einige Beziehungen zwischen abiotischen und biotischen Komponenten. Dissertation, TU Dresden, Fakultät Bau-, Wasser- und Forstwesen. 84 pp.

Weiss R, 1970. The solubility of nitrogen, oxygen, and argon in water and seawater. *Deep-Sea Research* 17, 721-35.

Wagner R, 1979. Die Praxis der Bestimmung des biochemischen Sauerstoffbedarfs - Ergebnisse einer Umfrage (Berichtigung und Ergänzung zur Veröffentlichung). *Vom Wasser* 53, S. 283-285.

## See Also

[gas\\_satconc](#) for other gas species and explicit consideration of pressure.

## Examples

```
gas_O2sat(S = 0, t = 20)           # fresh water, Weiss formula
gas_O2sat(S = 0, t = 20, method = "APHA") # fresh water, APHA formula

## compare this with
gas_satconc(S = 0, t = 20, species = "O2") * molweight("O2") / 1000

T <- seq(0, 30, 0.1)
plot(T, gas_O2sat(S = 0, t = T, method = "APHA"),
     ylab="O2 sat (mg/L)", type = "l", ylim = c(0, 15))
lines(T, gas_O2sat(S = 0, t = T, method = "Weiss"),
     col = "blue", lwd = 2, lty = "dashed")
```



```

lines(T, gas_02sat(S = 5, t = T, method = "Weiss"), col = "green")
lines(T, gas_02sat(S = 10, t = T, method = "Weiss"), col = "yellow")
lines(T, gas_02sat(S = 20, t = T, method = "Weiss"), col = "orange")
lines(T, gas_02sat(S = 35, t = T, method = "Weiss"), col = "red")

legend("bottomleft",
      col = c("black", "white", "blue", "green", "yellow", "orange", "red"),
      lty = c(1, 0, 2, 1, 1, 1, 1), lwd = c(1,0,2, 1, 1, 1, 1),
      legend=c("freshwater formula", "marine formula:",
              "S = 0", "S = 5", "S = 10", "S = 20", "S = 35"))

```

---

 gas\_satconc

*Saturated Concentrations of Gases in Water*


---

### Description

Calculates the saturated concentration of several gases in water for a given temperature, salinity and pressure.

### Usage

```

gas_satconc(S = 35, t = 25, P = 1.013253,
            species =c("He", "Ne", "N2", "O2", "Ar", "Kr", "CH4", "CO2", "N2O"),
            atm = atmComp(species))

```

### Arguments

S	Salinity (dimensionless),
t	Temperature, °C,
P	True pressure, bar
species	character vector with gasses whose saturated concentration should be estimated.
atm	The number of moles of the gas per unit mole of air in the atmosphere, the "mixing ratio". When present, this overrules the species argument. When unspecified, the value from atmComp for the species is taken.

### Value

The saturated concentration of the gas in  $mmolm^{-3}$ .

### Note

Compared to the table in Sarmiento and Gruber, there is a slight deviation for N<sub>2</sub>O, and He. CO<sub>2</sub> is OK for temperature 0 only.

### Author(s)

Karline Soetaert <karline.soetaert@nioz.nl>

## References

Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 85.

who cite:

for He and Ne: Weiss R, 1971. Solubility of helium and neon in water and seawater. Journ. Chem. Eng. Data 16, 235-241.

N<sub>2</sub>, O<sub>2</sub> and Ar: Weiss R, 1970. The solubility of nitrogen, oxygen, and argon in water and seawater. Deep-Sea Res. 17, 721-35.

Kr: Weiss R and Kyser TK, 1978. Solubility of Krypton in water and seawater. Journ. Chem. Eng. Data 23, 69-72.

Rn: Hackbusch 1979. Eine Methode zur Bestimmung der Diffusions-, Löslichkeits und Permeabilitäts Konstanten von Radon-222 in Wasser und Meereswasser. Dissertation, University of Heidelberg, Germany.

CH<sub>4</sub>: Wiesenburg DA and Guinasso JNL, 1979. Equilibrium solubilities of methane, carbon monoxide and hydrogen in water and sea water. Journ. Chem. Eng. Data 24, 256-360.

CO<sub>2</sub> and N<sub>2</sub>O: Weiss R and Price BA, 1980. Nitrous oxide solubility in water and seawater. Mar. Chem. 8, 347-359.

CFC-11 and CFC-12: Warner MJ and Weiss R, 1985. Solubilities of chlorofluorocarbons 11 and 12 in water and seawater. Deep-Sea Res. 32, 1485-1497.

SF<sub>6</sub>: Bullister et al., 2002. The solubility of sulfur hexafluoride in water and seawater. Deep-Sea Res. I, 49, 175-188.

CCl<sub>4</sub>: Bullister JL and Wisegarver DP, 1998. The solubility of carbon tetrachloride in water and seawater. Deep-Sea Res. I, 1285-1302.

## See Also

[gas\\_02sat](#), [gas\\_schmidt](#), [gas\\_solubility](#), [gas\\_transfer](#), [atmComp](#), [vapor](#)

## Examples

```
gas_satconc(species = "O2")
Temp <- seq(from = 0, to = 30, by = 0.1)
Sal <- seq(from = 0, to = 35, by = 0.1)

mf <- par(mfrow = c(1,2))

species <- c("N2", "CO2", "O2", "CH4", "N2O")
gsat <- gas_satconc(t = Temp, species = species)

matplot(Temp, gsat, type = "l", xlab = "temperature", log = "y", lty = 1,
         ylab = "mmol/m3", main = "Saturated conc (S=35)", lwd = 2)
legend("right", col = 1:5, lwd = 2, legend = species)

gsat <- gas_satconc(S = Sal, species = species)
matplot(Sal, gsat, type = "l", xlab = "salinity", log = "y", lty = 1,
         ylab = "mmol/m3", main = "Saturated conc (T=20)", lwd = 2)
legend("right", col = 1:5, lwd = 2, legend = species)
```

```

par(mfrow = mf)

## generate table 3.2.4 from Sarmiento and Gruber
Temp <- seq (0, 30, by = 5)
## saturated concentrations in mmol/m3, at 1 atm.
A <- data.frame(cbind( t = Temp,
                      N2 = gas_satconc(t = Temp, species = "N2"),
                      O2 = gas_satconc(t = Temp, species = "O2"),
                      CO2 = gas_satconc(t = Temp, species = "CO2"),
                      Ar = gas_satconc(t = Temp, species = "Ar")))
format(A, digits = 4)
## table values
## at 0 dg C: 635.6  359.1  23.37  17.44
## at 20 dg C: 425.7  230.5  11.61  11.29
## note the deviations for CO2 (20dg)!

## saturated concentrations in micromol/m3, at 1 atm.
AA <- data.frame(cbind(t = Temp,
                      N20 = gas_satconc(t = Temp, species = "N20")*1000,
                      Ne = gas_satconc(t = Temp, species = "Ne" )*1000,
                      Kr = gas_satconc(t = Temp, species = "Kr" )*1000,
                      CH4 = gas_satconc(t = Temp, species = "CH4")*1000,
                      He = gas_satconc(t = Temp, species = "He" )*1000))
format(AA, digits = 4)
## table values
## at 0 dgC: 14.84 8.11  4.33  3.44  1.81
## at 20 dgC: 7.16  6.94  2.50  2.12  1.70
## Note: different for N20

```

---

gas\_schmidt

*The Schmidt Number for Gases in Seawater*


---

## Description

The Schmidt number as a function of temperature (0-30dgC) and for a salinity of 35.

$$Sc = v/D = \mu u / (\rho \nu + D)$$

where  $v$  is the kinematic viscosity of the water and  $D$  is the mass diffusivity,  $\rho$  is density and  $\mu$  is the viscosity.

Schmidt numbers are used to estimate the gas transfer velocity.

## Usage

```

gas_schmidt(t = 25, species = c("He", "Ne", "N2", "O2", "Ar",
                               "Kr", "Rn", "CH4", "CO2", "N2O", "CCl2F2", "CCL3F",
                               "SF6", "CCl4"))

```

**Arguments**

t                    Temperature in °C,  
species            character vector with gasses whose schmidt number should be estimated.

**Value**

The Schmidt number, a dimensionless quantity.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 85.

who cite:

Wanninkhof R, 1992. Relationship between wind speed and gas exchange over the ocean. Journ. Geophys. Res. 97, 7373-7383.

except for  $O_2$ :

Keeling et al., 1998. Seasonal variation in the atmospheric  $O_2/N_2$  ratio in relation to the kinetics of air-sea gas exchange. Global Biogeochemical Cycles 12, 141-164.

CFC-11 ( $CCl_2F_2$ ), and CFC-12 ( $CCl_3F$ ):

Zheng et al., 1998. Measurements of the diffusion coefficients of CF-11 and CF-12 in pure water and seawater. Journ. Geophys. Res. 103, 1375-1379.

and  $CCl_4$  (Wanninkhof, pers.comm).

**See Also**

[gas\\_02sat](#), [gas\\_satconc](#), [gas\\_solubility](#), [gas\\_transfer](#), [atmComp](#), [vapor](#)

**Examples**

```
gas_schmidt(species = "CO2", t = 20) # about 660
```

---

gas\_solubility

*Solubility Parameters*

---

**Description**

Solubility parameters SA,  $mmolm^{-3}bar^{-1}$ , calculated from the Bunsen solubility coefficients and the volumetric solubility coefficients.

**Usage**

```
gas_solubility(S = 35, t = 25,
  species = c("He", "Ne", "N2", "O2", "Ar", "Kr", "Rn", "CH4",
    "CO2", "N2O", "CCl2F2", "CCl3F", "SF6", "CCl4"))
```

**Arguments**

S	salinity, -
t	temperature, °C,
species	The gas

**Value**

The solubility, mmol/m<sup>3</sup>/bar.

**Note**

The molar volume used for the Bensen coefficient conversion is the ideal gas value of 22.4136 l/mol.

These coefficients are to be used with pAmoist, the partial pressure of the gas in moist air.

To convert them for use with partial pressure in dry air, divide by (1-vapor(S,t)).

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 85.

who cite:

for He and Ne: Weiss R, 1971. Solubility of helium and neon in water and seawater. Journ. Chem. Eng. Data 16, 235-241.

N<sub>2</sub>, O<sub>2</sub> and Ar: Weiss R, 1970. The solubility of nitrogen, oxygen, and argon in water and seawater. Deep-Sea Res. 17, 721-35.

Kr: Weiss R and Kyser TK, 1978. Solubility of Krypton in water and seawater. Journ. Chem. Eng. Data 23, 69-72.

Rn: Hackbusch 1979. Eine Methode zur Bestimmung der Diffusions, Löslichkeits und Permeabilitäts Konstanten von Radon-222 in Wasser und Meereswasser. Dissertation, University of Heidelberg, Germany.

CH<sub>4</sub>: Wiesenburg DA and Guinasso JNL, 1979. Equilibrium solubilities of methane, carbon monoxide and hydrogen in water and sea water. Journ. Chem. Eng. Data 24, 256-360.

CO<sub>2</sub> and N<sub>2</sub>O: Weiss R and Price BA, 1980. Nitrous oxide solubility in water and seawater. Mar. Chem. 8, 347-359.

CFC-11 and CFC-12: Warner MJ and Weiss R, 1985. Solubilities of chlorofluorocarbons 11 and 12 in water and seawater. Deep-Sea Res. 32, 1485-1497.

SF6: Bullister et al., 2002. The solubility of sulfur hexafluoride in water and seawater. Deep-Sea Res. I, 49, 175-188.

CCl4: Bullister JL and Wisegarver DP, 1998. The solubility of carbon tetrachloride in water and seawater. Deep-Sea Res. I, 1285-1302.

### See Also

[gas\\_02sat](#), [gas\\_satconc](#), [gas\\_schmidt](#), [gas\\_transfer](#), [atmComp](#), [vapor](#)

### Examples

```
gas_solubility(t = 1:20, S = 35, species = "CO2")
gas_solubility(t = 0:5, S = 35, species = "O2")

Temp <- seq(from = 0, to = 30, by = 0.1)
mf <- par(mfrow = c(1, 2))
gs <- gas_solubility(t = Temp)
species <- c("CCl4", "CO2", "N2O", "Rn", "CCl2F2")
matplot(Temp, gs[, species], type = "l", lty = 1, lwd = 2,
         xlab = "temperature", ylab = "mmol/m3", main = "solubility (S=35)")
legend("topright", col = 1:5, lwd = 2, legend = species)

species2 <- c("Kr", "CH4", "Ar", "O2", "N2", "Ne")
matplot(Temp, gs[, species2], type = "l", lty = 1, lwd = 2,
         xlab = "temperature", ylab = "mmol/m3", main = "solubility (S=35)")
legend("topright", col = 1:6, lwd = 2, legend = species2)

plot(Temp, gas_solubility(t = Temp, species = "CCl4"), xlab = "temperature",
     ylab = "mmol/m3/atm", main = "solubility (S=35)",
     type = "l", lwd = 2, ylim = c(0, 100000))
lines(Temp, gas_solubility(t = Temp, species = "CO2"), col = "red", lwd = 2)
lines(Temp, gas_solubility(t = Temp, species = "N2O"), col = "blue", lwd = 2)
lines(Temp, gas_solubility(t = Temp, species = "Rn"), col = "green", lwd = 2)
lines(Temp, gas_solubility(t = Temp, species = "CCl2F2"), col = "yellow", lwd = 2)

legend("topright", col = c("black", "red", "blue", "green", "yellow"), lwd = 2,
     legend = c("CCl4", "CO2", "N2O", "Rn", "CCl2F2"))

plot(Temp, gas_solubility(t = Temp, species = "Kr"), xlab = "temperature",
     ylab = "mmol/m3/atm", main = "solubility (S=35)", type = "l",
     lwd = 2, ylim = c(0, 4000))
lines(Temp, gas_solubility(t = Temp, species = "CH4"), col = "red", lwd = 2)
lines(Temp, gas_solubility(t = Temp, species = "Ar"), col = "blue", lwd = 2)
lines(Temp, gas_solubility(t = Temp, species = "O2"), col = "green", lwd = 2)
lines(Temp, gas_solubility(t = Temp, species = "N2"), col = "yellow", lwd = 2)
lines(Temp, gas_solubility(t = Temp, species = "Ne"), col = "grey", lwd = 2)
```

```

legend("topright",col = c("black", "red", "blue", "green", "yellow", "grey"),
      lwd = 2, legend = c("Kr", "CH4", "Ar", "O2", "N2", "Ne"))

par(mfrow = mf)

## generate table 3.2.3 from Sarmiento and Gruber
Temp <- seq (0,30,by = 5)

## saturated concentrations in mmol/m3 at at 1 atm;
# convert from /bar to /atm using 1.013253

A <- data.frame(cbind( t = Temp,
                      He = gas_solubility(t = Temp,species = "He")*1.013253,
                      Ne = gas_solubility(t = Temp,species = "Ne")*1.013253,
                      N2 = gas_solubility(t = Temp,species = "N2")*1.013253,
                      O2 = gas_solubility(t = Temp,species = "O2")*1.013253,
                      Ar = gas_solubility(t = Temp,species = "Ar")*1.013253,
                      Kr = gas_solubility(t = Temp,species = "Kr")*1.013253,
                      Rn = gas_solubility(t = Temp,species = "Rn")*1.013253) )
format(A,digits = 4)
## table values at
## 0 dgC: 349.4 448.6 818.8 1725 1879 3820 31150
## 20 dg C: 332.9 390.7 557.9 1126 1236 2241 14130
## note the (very) slight deviations for Rn

## saturated concentrations in micromol/m3 at 1 atm
AA <- data.frame(cbind( t = Temp,
                       CH4 = gas_solubility(t = Temp,species = "CH4") *1.013253,
                       CO2 = gas_solubility(t = Temp,species = "CO2") *1.013253,
                       N2O = gas_solubility(t = Temp,species = "N2O") *1.013253,
                       CCL2F2 = gas_solubility(t = Temp,species = "CCL2F2")*1.013253,
                       CCL3F = gas_solubility(t = Temp,species = "CCL3F") *1.013253,
                       SF6 = gas_solubility(t = Temp,species = "SF6") *1.013253,
                       CCL4 = gas_solubility(t = Temp,species = "CCL4") *1.013253))
format(AA,digits = 4)

## Table values at
## 0 dgC: 1984 64400 47840 6686 27380 425.2 97114
## 20 dgC: 1241 33110 23870 2566 9242 195.8 30307
## Note: there are slight deviations for CO2, and N2O!

```

---

gas\_transfer

*The Gas Transfer Coefficient in m/sec*


---

## Description

The gas transfer coefficient, in  $m s^{-1}$ , for certain gases in seawater ( $S = 35$ ).

**Usage**

```
gas_transfer(t = 25, u10 = 1, species = c("He", "Ne", "N2", "O2", "Ar",
    "Kr", "Rn", "CH4", "CO2", "N2O", "CCl2F2", "CCL3F",
    "SF6", "CCl4"),
    method = c("Liss", "Nightingale", "Wanninkhof1", "Wanninkhof2"),
    Schmidt = gas_schmidt(t = t, species = species))
```

**Arguments**

t	Temperature in °C,
u10	wind speed, in m/sec at a nominal height of 10 m above sea level,
species	character vector with gasses whose gas transfer coefficient should be estimated.
method	one of "Liss", for Liss and Merlivat, 1986; "Nightingale", for Nightingale et al., 2000; "Wanninkhof1", for Wanninkhof 1992, or "Wanninkhof2" for Wanninkhof and McGills 1999.
Schmidt	the Schmidt number, when given this overrules the arguments gas and t.

**Value**

The gas transfer velocity, for seawater, in  $ms^{-1}$ .

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

- Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 85.
- Liss PS and Merlivat L, 1986. Air-sea gas exchange rates: introduction and synthesis. In: the role of air-sea exchange in Geochemical cycling, edited by P. Buat-Menard, pp 113-127. D. Reidel, Dordrecht, the Netherlands.
- Nightingale et al., 2000. In situ evaluation of air-sea gas exchange parameterizations using novel conservative and volatile tracers. Global biogeochemical cycles 14, 373-387.
- Wanninkhof R, 1992. Relationship between wind speed and gas exchange over the ocean. Journ. Geophys. Res. 97, 7373-7383.
- Wanninkhof R and McGillis W, 1999. A cubic relationship between air-sea CO<sub>2</sub> exchange and wind speed. Geophys. Res. Lett. 26, 1889-1892.

**See Also**

[gas\\_02sat](#), [gas\\_satconc](#), [gas\\_schmidt](#), [gas\\_solubility](#), [atmComp](#), [vapor](#)



**Examples**

```

useq <- 0:15
plot(useq, gas_transfer(u10 = useq, species = "O2"), type = "l", lwd = 2, xlab = "u10, m/s",
     ylab = "m/s", main = "O2 gas transfer velocity", , ylim = c(0, 0.0003))
lines(useq, gas_transfer(u10 = useq, species = "O2", method = "Nightingale"), lwd = 2, lty = 2)
lines(useq, gas_transfer(u10 = useq, species = "O2", method = "Wanninkhof1"), lwd = 2, lty = 3)
lines(useq, gas_transfer(u10 = useq, species = "O2", method = "Wanninkhof2"), lwd = 2, lty = 4)

legend("topleft", lty = 1:4, lwd = 2,
      legend = c("Liss and Merlivat 1986", "Nightingale et al. 2000",
                "Wanninkhof 1992", "Wanninkhof and McGills 1999"))

```

gravity

*Gravity on Earth***Description**

Computes the gravity, based on latitude.

**Usage**

```
gravity(lat = 0, method = c("Moritz", "UNESCO"))
```

**Arguments**

lat	latitude (-90 - +90).
method	When "UNESCO", uses the UNESCO (1983) polynomial, else according to Moritz, 2000

**Value**

Gravity, in  $\text{m sec}^{-2}$ .

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

The UNESCO polynomial:

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.

<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

Moritz H, 2000. Geodetic reference system 1980. Journal of Geodesy 74, 128-133.

**See Also**

[coriolis](#), [viscosity](#), [diffcoeff](#), [ssd2rad](#), [vertmean](#)

**Examples**

```
gravity(lat = 30)
```

---

 molvol

---

*Mol to Liter Conversion for a Gas*


---

**Description**

Converts from liter to moles for a gas.

**Usage**

```
molvol(t = 25, P = 1.013253,
       species = c("ideal", "Ar", "CO2", "CS2", "CO", "CCl4", "Cl2",
                  "C2H6S", "C2H5OH", "C6H5F", "CH3F", "CH4", "CH3OH", "C5H12",
                  "C3H8", "H2O", "He", "H2", "HBr", "HCl", "H2S", "Hg",
                  "Kr", "NH3", "Ne", "NO", "N2", "NO2", "N2O", "O2", "PH3",
                  "SiH4", "SiF4", "SO2", "Xe"),
       quantity = 1, a = 0, b = 0)
```

**Arguments**

t	temperature, °C
P	True pressure, bar.
species	character vector with gasses whose molecular volume should be estimated. if NULL then the coefficients a and b are used.
quantity	mol of the gas.
a	Van der Waals constant a, a species-specific coefficient, $dm^6 * bar/mol^2$ .
b	Van der Waals constant b, a species-specific coefficient, $dm^3/mol$ .

**Value**

volume of the gas, liter

**Note**

The coefficients a and b are species-specific; values of 0 assume an ideal gas and in general give good estimates.

Use 1/molvol to convert from liter to moles.

The default calculates the molar volume of an ideal gas

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

The values of the van der Waals constants are from:

Weast RC (Ed.) 1972. Handbook of Chemistry and Physics (53rd Edn.), Cleveland:Chemical Rubber Co.

as found in: [http://en.wikipedia.org/wiki/Van\\_der\\_Waals\\_constants\\_\(data\\_page\)](http://en.wikipedia.org/wiki/Van_der_Waals_constants_(data_page))

**See Also**

[AtomicWeight](#), [molweight](#), [redfield](#)

**Examples**

```
#molecular volume of an ideal gas.
molvol(species = "ideal", P = 1, t = 0)    # 22.710 980
molvol(species = "ideal", P = 1, t = 25)  # 24.789 598

plot(0:30, molvol(t = 0:30, species = NULL),
     xlab = "Temperature, dgC", ylab = "Molar volume")

#
molvol(a = 1.382, b = 0.03186, species = NULL, t = 0)

molvol(t = 0, species = "O2")

# the same but for all gasses
molvol(t = 0)

# table for different pressures
molvol(P = 1:5, species = "O2")

# the inverse function
1/molvol(species = "O2")

# contour plot
P    <- seq(1, 100, by = 1)
Temp <- seq(-5, 40, by = 1)

Val <- outer(X = P, Y = Temp,
             FUN = function(X, Y) molvol(P = X, t = Y, species = "O2"))
contour(P, Temp, Val, xlab = "pressure", ylab = "temperature",
        main = "molvol", nlevel = 20, log = "x", axes = FALSE)
axis(1); axis(2); box()
```

---

molweight

*Molecular Weight of a Chemical Species*

---

### Description

Calculates the molecular weight of chemical species.

### Usage

```
molweight(species)
```

### Arguments

species            character vector with chemical species whose molecular weight is requested.

### Details

Molecular weights of chemical elements may vary due to different isotope compositions, depending on geology, industrial processes or biological activity. Please consult the IUPAC Technical report about the details. The function returns NA for elements (and their compounds) which have no stable isotopes (except U, Th, Pa).

### Value

Vector with the molecular weights in g/mol.

### Note

This function uses text parsing of chemical formulae, it is strictly case sensitive.

### Author(s)

Thomas Petzoldt

### References

Wieser ME, 2006. Atomic weights of the elements 2005 (IUPAC Technical Report). Pure Appl. Chem. 78(11), 2051–2066. doi:10.1351/pac200678112051

### See Also

[AtomicWeight](#), [molvol](#), [redfield](#)

**Examples**

```
molweight("CO2")
molweight("HCO3")
molweight("H")
molweight("H3PO4")

## eicosapentaenoic acid (EPA)
molweight("CH3CH2CHCHCH2CHCHCH2CHCHCH2CHCHCH2CHCH(CH2)3COOH")
molweight("C20H30O2")

## works also with vectors
molweight(c("C2H5OH", "CO2", "H2O"))
molweight(c("SiOH4", "NaHCO3", "C6H12O6", "Ca(HCO3)2", "Pb(NO3)2", "(NH4)2SO4"))

## note that chemical formulae are case-sensitive
molweight("Co") # cobalt
molweight("CO") # carbon monoxide

## from gram to mol
1/molweight("CO3")
```

---

Oceans

*Useful Characteristics of the Oceans*

---

**Description**

Surface area and volume of the world's oceans

**Usage**

Oceans

**Format**

A list specifying the value, units, and a description of each quantity.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 85.

**See Also**

[AtomicWeight](#), [Bathymetry](#), [Constants](#), [earth\\_surf](#)

## Examples

```
data.frame(cbind(acronym = names(Oceans),
                matrix(ncol = 3, byrow = TRUE, data = unlist(Oceans),
                      dimnames = list(NULL, c("value", "units", "description")))))
```

---

 redfield

*Redfield Ratio Calculator*


---

## Description

Estimate elemental composition of biomass (or media) according to the Redfield ratio.

## Usage

```
redfield(q, species, method = c("mol", "mass"),
         ratio = c(C=106, H=263, O=110, N=16, P=1))
```

## Arguments

q	amount of substance of that element (in mol or mass units),
species	The element that is given ("C", "H", "O", "N", "P"),
method	measurement unit ("mol" or "mass"),
ratio	average elemental composition.

## Details

The average elemental composition of marine plankton (Redfield ratio) is traditionally assumed to be  $C_{106}H_{263}O_{110}N_{16}P_1$  (Redfield 1934, 1963, Richards 1965). Note that while the C:N:P ratio is widely agreed there is still discussion about the average of O and H, e.g.  $C_{106}H_{180}O_{45}N_{16}P_1$  (Stumm, 1964).

Note also that there are, of course, large differences depending on species and physiological state.

## Value

A data frame with the estimated ratio of the main elements.

## References

Redfield AC, 1934. On the proportions of organic derivations in sea water and their relation to the composition of plankton. In: James Johnstone Memorial Volume. (ed. R.J. Daniel). University Press of Liverpool, 177-192.

Redfield, AC, Ketchum, BH and Richards FA, 1963. The influence of organisms on the composition of seawater. In: Hill, MN, Editor, The Sea vol. 2, Interscience, New York (1963), pp.26-77.

Richards FA, 1965. Anoxic basins and fjords. In: Riley JP, Skirrow D. (Eds.), Chemical Oceanography, vol. 1. Academic Press, New York, 611-645. (cited in Hedges et al, 2002).

Stumm W, 1964. Discussion (Methods for the removal of phosphorus and nitrogen from sewage plant effluents by G. A. Rohlich). In Eckenfelder, WW (ed.), Advances in water pollution research. Proc. 1st Int. Conf. London 1962, volume 2, pp. 216-229. Pergamon.

Vollenweider RA, 1985. Elemental and biochemical composition of plankton biomass: some comments and explorations. Arch. Hydrobiol. 105, 11-29.

Anderson LA, 1995. On the hydrogen and oxygen content of marine plankton. Deep-Sea Res. 42, 1675-1680.

Hedges JJ., Baldock JA, Gelinas Y, Lee C, Peterson ML and Wakeham SG, 2002. The biochemical and elemental compositions of marine plankton: A NMR perspective. Marine Chemistry 78, 47-63.

### See Also

[AtomicWeight](#), [molvol](#), [molweight](#)

### Examples

```
## Redfield ratio
redfield(1, "P")
## returns the molar Redfield ratio, rescaled to nitrogen
redfield(1, "N")
## how many mass units are related to 2 mass units (e.g. mg) P
redfield(2, "P", "mass")
redfield(c(1, 2, 3), "N", "mass")

## mass percentage of elements
x <- redfield(1, "P", "mass")
x / sum(x)

## with alternative elemental composition (Stumm, 1964)
x <- redfield(1, "P", "mass",
             ratio = c(C = 106, H = 180, O = 45, N = 16, P = 1))
x / sum(x)

## rule of thumb for fresh mass (in mg) formed by 1 microgram P
redfield(1, "P", "mass")$C * 2 * 10 / 1000
sum(redfield(1, "P", "mass",
             ratio = c(C = 106, H = 180, O = 45, N = 16, P = 1))) * 10 / 1000
```

---

ssd2rad

---

*Estimate Global Radiation from Measured Sunshine Duration Time*


---

### Description

The function converts values of sunshine duration (in hours) to global radiation (in  $Jm^{-2}s^{-1}$ ).

### Usage

```
ssd2rad(S, doy, a = 0.25, b = 0.5, rho = 50.29)
```

**Arguments**

S	Sunshine duration (hours)
doy	Julian day (for northern hemisphere only)
a, b, rho	site specific conversion parameters, must be fitted to measured data.

**Value**

Estimated value of global radiation in  $Jm^{-2}s^{-1}$ .

**Note**

Don't forget to fit the function parameters to site specific values!

**References**

Dyck S and Peschke G., 1995. Grundlagen der Hydrologie. 3. Auflage. Verlag für Bauwesen, Berlin 1995, ISBN 3-345-00586-7.

**See Also**

[coriolis](#), [viscosity](#), [diffcoeff](#), [vertmean](#), [gravity](#)

**Examples**

```
ssd2rad(8, 120)
```

---

sw\_adtgrad

*Adiabatic Temperature Gradient in Seawater*

---

**Description**

Computes the adiabatic temperature gradient in seawater, using the UNESCO 1983 polynomial.

Also known as the adiabatic lapse rate, the change of temperature per unit pressure for an adiabatic change of pressure of an element of seawater. It is assumed that no heat or salt is exchanged with the surroundings.

**Usage**

```
sw_adtgrad(S = 35, t = 25, p = P-1.013253, P = 1.013253 )
```

**Arguments**

S	Practical salinity (-),
t	Temperature, °C
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar



**Value**

adiabatic temperature gradient, in dg K / bar

**Note**

Note: in the original formula, the units of sw\_adtgrad are dg K/dbar (here: dg K/bar).  
sw\_adtgrad for S = 40, t = 40, p = 1000 is 3.255976e-3

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.  
<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

**See Also**

[sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#),  
[sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

**Examples**

```
sw_adtgrad(t = 40, S = 40, p = 1000) #3.255976e-4

## Check values
sw_adtgrad(S = 25, t = 10, p = 0) # 0.1002e-3
sw_adtgrad(S = 25, t = 10, p = 100) # 0.1135e-3
sw_adtgrad(S = 25, t = 10, p = 1000) # 0.2069e-3

sw_adtgrad(S = 25, t = 30, p = 0) # 0.2417e-3
sw_adtgrad(S = 40, t = 30, p = 0) # 0.2510e-3
sw_adtgrad(S = 40, t = 0, p = 100) # 0.0630e-3
```

---

sw\_alpha

*Thermal Expansion Coefficient of Seawater*


---

**Description**

Computes the seawater thermal expansion coefficient with respect to in situ temperature, 1/K

**Usage**

```
sw_alpha(S = 35, t = 25, p = P-1.013253, P = 1.013253)
```

**Arguments**

S	Absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar

**Value**

Thermal expansion coefficient, 1/K.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. Deep-Sea Research I, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

[sw\\_tfreeze](#), [sw\\_tpot](#), [sw\\_adtgrad](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sf](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

[convert\\_PStoAS](#), to convert from practical salinity (-) to absolute salinity (g/kg)

**Examples**

```
sw_alpha(35.7, 25.5, 102.3)#0.000309837839319264
```

---

sw\_beta

*Haline Contraction Coefficient of Seawater*

---

**Description**

Computes the seawater haline contraction coefficient with respect to constant, in situ temperature, kg/g

**Usage**

```
sw_beta(S = 35, t = 25, p = P-1.013253, P = 1.013253)
```

**Arguments**

S	Absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar

**Value**

Haline contraction coefficient, kg/g.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. Deep-Sea Research I, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sf](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)  
[convert\\_PStoAS](#), to convert from practical salinity (-) to absolute salinity (g/kg)

**Examples**

```
sw_beta(35.7, 25.5, 102.3) #0.000725729797838666
```

---

sw\_comp

*Reference Sea Salt Composition*

---

**Description**

The sea salt composition definition for reference salinity of the standard ocean at 25 dgC and 1.01325 bar (atmospheric pressure), given in mass fractions).

**Usage**

```
sw_comp(species = c("Na", "Mg", "Ca", "K", "Sr", "Cl", "S04", "HC03",  
"Br", "C03", "BOH4", "F", "OH", "BOH3", "C02"))
```

**Arguments**

species            character vector with components whose composition should be estimated.

**Value**

A vector with the mass fractions.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Millero FJ, Waters J, Woosley R, Huang F and Chanson M, 2008. The effect of composition of the density of Indian Ocean waters, Deep-Sea Res. I, 55, 960-470.

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

**Examples**

```
sw_comp("CO2")
sw_comp()
sum(sw_comp())
```

---

sw\_conserv

*Concentrations of (Conservative) Species in Seawater*

---

**Description**

Estimates the concentration of Borate, Calcite, Sulphate and Fluoride in seawater, as a function of salinity.

**Usage**

```
sw_conserv(S = 35)
```

**Arguments**

S                    Practical salinity, (-).

**Details**

The borate and calcite concentration as in Millero (1995),  
Sulphate as in Morris and Riley, 1966,  
Fluoride as in Riley, 1965.

**Value**

A data frame with the concentrations in micromol/kg.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Millero FJ, 1995. Thermodynamics of the carbon dioxide system in the oceans. *Geochim. Cosmochim. Acta* 59, 661-677.

Riley JP, 1965. The occurrence of anomalously high fluoride concentrations in the North Atlantic. *Deep-Sea Res.* 12, 219-220.

Morris AW, Riley JP, 1966. The bromide- chlorinity and sulphate- chlorinity ratio in seawater. *Deep-Sea Res.* 13, 699-706.

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

**Examples**

```
data.frame(salinity = 1:35, sw_conserv(1:35) )
```

---

sw_cp	<i>Heat Capacity of Sea Water</i>
-------	-----------------------------------

---

**Description**

Estimates the heat capacity of seawater.

Valid for S = 0 to 40, T = 0 to 35 dg C

**Usage**

```
sw_cp(S = 35, t = 25, p = P-1.013253, P = 1.013253,
      method = c("Gibbs", "UNESCO"))
```

**Arguments**

S	Salinity, when method = "UNESCO": practical salinity (-) else absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar
method	When "UNESCO", uses the UNESCO (1983) polynomial, when "Gibbs", based on the gibbs functions as in Feistel, 2008

**Value**

Heat capacity, in  $Jkg^{-1}dgC^{-1}$

**Note**

p is applied pressure, 0 bar at sea surface.

when using UNESCO polynomial, cp for S = 40, T = 40, P = 1000 is 3849.5 J/(kg dg C).

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.

<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. Deep-Sea Research I, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

[convert\\_PStoAS](#), to convert from practical salinity (-) to absolute salinity (g/kg)

[convert\\_AStoPS](#), to convert from absolute salinity (g/kg) to practical salinity (-)

**Examples**

```
sw_cp(S = 40, t = 40, p = 1000, method="UNESCO") # 3849.5

# Check value Gibbs function
sw_cp(35.7, 25.5, 102.3)#3974.42541259729

# Check values UNESCO
sw_cp(S = 25, t = 10, p = 0, method = "UNESCO") # 4041.8
sw_cp(S = 25, t = 10, p = 1000, method = "UNESCO") # 3842.3
sw_cp(S = 25, t = 30, p = 0, method = "UNESCO") # 4049.1

sw_cp(S = 40, t = 10, p = 0, method = "UNESCO") # 3959.3
```

---

sw\_dens                      *Density of Sea Water*

---

### Description

Density of sea water in  $kgm^{-3}$

### Usage

```
sw_dens(S = 35, t = 25, p = max(0, P-1.013253), P = 1.013253,
        method=c("Gibbs", "UNESCO", "Chen"))
```

### Arguments

S	Salinity, when method = "UNESCO": practical salinity (-) else absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar
method	When "UNESCO", uses the UNESCO (1983) polynomial, when "Gibbs", based on the Gibbs functions as in Feistel, 2008 "Chen" for the limnological range (i.e. fresh water systems).

### Details

To avoid confusion between the arguments (S, t, p) it is advisable to use named arguments in general (e.g. rho(t = 4)). The UNESCO formula is imported from package **seacarb**.

### Value

Density of water in  $kgm^{-3}$ .

### Note

Pressure used here is 1 bar (true pressure), in contrast to hydrostatic pressure (0 bar at surface) in original formula.

The coefficients from McDougall et al., 2009 were used. For temperature, they differ slightly from Feistel 2003 and Feistel 2008, which is why, for temperatures different from 0, there is a slight offset from the estimates as from table 22 or 21 from Feistel (2008).

## References

Chen Ch.-T. and Millero FJ, 1986. Precise thermodynamic properties of natural waters covering only the limnological range. *Limnol. Oceanogr.* 31 No. 3, 657 - 662.

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.

<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. *Deep-Sea Research I*, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

## See Also

[rho](#) in package seacarb.

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sf](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

[convert\\_PStoAS](#), to convert from practical salinity to absolute salinity

[convert\\_AStoPS](#), to convert from absolute salinity to practical salinity

## Examples

```
# table 22 Feistel 2008
sw_dens(0, 0, 0)           #0.999843086e3
sw_dens(0, 79.85, 0)      #0.97188383e3 - deviates
sw_dens(0, 0, 998.98675)  #0.104527796e4

# table 21 Feistel 2008
sw_dens(35.16504, 0, 0)    #0.10281072e4
sw_dens(100, 79.85, 0)    #0.102985888e4
sw_dens(35.16504, 0, 998.98675) #0.10709264e4

sw_dens(35.7, 25.5, 102.3) #1027.95249315662

S <- 0:40
plot(S, sw_dens(S = S, t = 4, method = "UNESCO"))

lines(S, sw_dens(S = S, t = 4, method = "Gibbs"), col = "red")

lines(S, sw_dens(S = S, t = 4, method = "Chen"), col = "blue")
```



---

sw_depth	<i>Water Depth</i>
----------	--------------------

---

**Description**

Computes the water depth for water of salinity 35, and temperature 0 dg C, based on latitude and hydrostatic pressure, using the UNESCO 1983 polynomial.

**Usage**

```
sw_depth(p = P-1.013253, P = 1.013253, lat = 0)
```

**Arguments**

p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar
lat	latitude (-90 to +90), -,

**Value**

Water depth in m.

**Note**

sw\_depth for p = 1000, lat = 30 is 9712.653 m.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.  
<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

**Examples**

```
sw_depth(p = 1000, lat = 30:40)

## Check values
sw_depth(p = 1000, lat = 30)      #9712.65
sw_depth(p = 50, lat = 30)       #496.00
sw_depth(p = 50, lat = 60)       #494.69
sw_depth(p = 500, lat = 60)      #4895.60
```

---

sw_enthalpy	<i>Specific Enthalpy of Seawater</i>
-------------	--------------------------------------

---

**Description**

Computes the seawater specific enthalpy, J/kg

**Usage**

```
sw_enthalpy(S = 35, t = 25, p = P-1.013253, P = 1.013253)
```

**Arguments**

S	Absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar

**Value**

Specific enthalpy, J/kg.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. *Deep-Sea Research I*, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)  
[convert\\_PStoAS](#), to convert from practical salinity (-) to absolute salinity (g/kg)

**Examples**

```
sw_enthalpy(35.7, 25.5, 102.3) #110776.712408975
```

---

sw_entropy	<i>Specific Entropy of Seawater</i>
------------	-------------------------------------

---

**Description**

Computes the seawater specific entropy, J/(kg\*K)

**Usage**

```
sw_entropy(S = 35, t = 25, p = P-1.013253, P = 1.013253)
```

**Arguments**

S	Absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar

**Value**

Specific entropy, J/(kg\*K).

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. *Deep-Sea Research I*, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, *Global Ship-based Repeat Hydrography Manual*, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

sw\_adtgrad, sw\_alpha, sw\_beta, sw\_comp, sw\_conserv, sw\_cp, sw\_dens, sw\_depth, sw\_enthalpy, sw\_gibbs, sw\_kappa, sw\_kappa\_t, sw\_sfac, sw\_svel, sw\_tfreeze, sw\_tpot  
 convert\_PStoAS, to convert from practical salinity (-) to absolute salinity (g/kg)

**Examples**

```
sw_entropy(35.7, 25.5, 102.3) #352.81879771528
```

---

 sw\_gibbs

*Gibbs Function of Seawater*


---

**Description**

Calculates the seawater specific gibbs free energy, including derivatives up to order 2, for a given temperature, salinity and pressure.

The Gibbs function of seawater  $g(S,t,p)$  is related to the specific enthalpy  $h$  and entropy  $s$ , by  $g = h - (273.15 \text{ K} + t) s$

**Usage**

```
sw_gibbs(S = 35, t = 25, p = P-1.013253,  
         P = 1.013253, dS = 0, dt = 0, dp = 0)
```

**Arguments**

S	Absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar
dS	order of the S derivative
dt	order of the t derivative
dp	order of the p derivative

**Value**

The Gibbs function, J/kg, or its derivative

**Note**

The gibbs function is defined as the sum of a pure water part and the saline part (IAPWS-08)

The coefficients from McDougall et al., 2009 were used. For temperature, they differ slightly from Feistel 2003 and Feistel 2008, which is why, for temperatures different from 0, there is a slight offset from the estimates as from table 22 or 21 from Feistel (2008).

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. Deep-Sea Research I, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfacs](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)  
[convert\\_PStoAS](#), to convert from practical salinity (-) to absolute salinity (g/kg)

**Examples**

```
# table 22 Feistel 2008
sw_gibbs(0, 0, 0)                #= 101.34274
sw_gibbs(0, 0, 0, dS = 1)       # 0
sw_gibbs(0, 0, 0, dt = 1)      #0.147643376
sw_gibbs(0, 0, 0, dp = 1)      #0.1000015694e-2
sw_gibbs(0, 0, 0, dS = 1, dp = 1) #0
sw_gibbs(0, 0, 0, dt = 1, dp = 1) #-0.677700318e-7

sw_gibbs(0, 79.85, 0)          #-0.446114969e5 differs (see note)
sw_gibbs(0, 79.85, 0, dt = 1)  #-0.107375993e4 differs
sw_gibbs(0, 79.85, 0, dp = 1)  #0.102892956e-2 differs
sw_gibbs(0, 79.85, 0, dS = 1, dp = 1) #0
sw_gibbs(0, 79.85, 0, dt = 1, dp = 1) #0.659051552e-6

sw_gibbs(0, 0, 998.98675)      #0.977303862e5
sw_gibbs(0, 0, 998.98675, dt = 1) #0.851466502e1
sw_gibbs(0, 0, 998.98675, dp = 1) #0.956683329e-3
sw_gibbs(0, 0, 998.98675, dS = 1, dp = 1) #0
sw_gibbs(0, 0, 998.98675, dt = 1, dp = 1) #0.199079571e-6

# table 21 Feistel 2008
sw_gibbs(35.16504, 0, 0)        #=0
sw_gibbs(35.16504, 0, 0, dS = 1) #0.639974067e2 differs
sw_gibbs(35.16504, 0, 0, dt = 1) #=0
sw_gibbs(35.16504, 0, 0, dp = 1) #0.972661217e-3
sw_gibbs(35.16504, 0, 0, dS = 1, dp = 1) #-0.759615412e-6
sw_gibbs(35.16504, 0, 0, dt = 1, dp = 1) #0.515167556e-7 !!!

sw_gibbs(100, 79.85, 0)        #-=-0.295243229e5 differs
sw_gibbs(100, 79.85, 0, dS = 1) #0.251957276e3
sw_gibbs(100, 79.85, 0, dt = 1) #-0.917529024e3 differs
```

```

sw_gibbs(100, 79.85, 0, dp = 1)           #0.971006828e-3   differs
sw_gibbs(100, 79.85, 0, dS = 1, dp = 1)  #-0.305957802e-6
sw_gibbs(100, 79.85, 0, dt = 1, dp = 1)  #0.146211315e-5

sw_gibbs(35.16504, 0, 998.98675)         #=-0.951294557e5
sw_gibbs(35.16504, 0, 998.98675, dS = 1) #-0.545861581e1
sw_gibbs(35.16504, 0, 998.98675, dt = 1) #0.160551219e2
sw_gibbs(35.16504, 0, 998.98675, dp = 1) #0.933770945e-3
sw_gibbs(35.16504, 0, 998.98675, dS = 1, dp = 1) #-0.640757619e-6
sw_gibbs(35.16504, 0, 998.98675, dt = 1, dp = 1) #0.245708012e-6

```

---

sw\_kappa

*Isentropic Compressibility of Seawater*


---

### Description

Computes the seawater isentropic compressibility, 1/bar

### Usage

```
sw_kappa(S = 35, t = 25, p = P-1.013253, P = 1.013253)
```

### Arguments

S	Salinity (dimensionless),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar

### Value

Isentropic compressibility, 1/bar

### Author(s)

Karline Soetaert <karline.soetaert@nioz.nl>

### References

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. *Deep-Sea Research I*, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

sw\_adtgrad, sw\_alpha, sw\_beta, sw\_comp, sw\_conserv, sw\_cp, sw\_dens, sw\_depth, sw\_enthalpy, sw\_entropy, sw\_gibbs, sw\_kappa\_t, sw\_sfac, sw\_svel, sw\_tfreeze, sw\_tpot

convert\_PStoAS, to convert from practical salinity (-) to absolute salinity (g/kg)

**Examples**

```
sw_kappa(35.7, 25.5, 102.3) #4.03386268546478e-6
```

---

 sw\_kappa\_t

---

*Isothermal Compressibility of Seawater*


---

**Description**

Computes the seawater isothermal compressibility, 1/Pa

**Usage**

```
sw_kappa_t(S = 35, t = 25, p = P-1.013253, P = 1.013253)
```

**Arguments**

S	Absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar

**Value**

isothermal compressibility, 1/Pa.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. Deep-Sea Research I, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

[convert\\_PStoAS](#), to convert from practical salinity (-) to absolute salinity (g/kg)

**Examples**

```
sw_kappa_t(35.7, 25.5, 102.3) #4.10403794615135e-6
```

---

sw\_sfac

*Salinity conversion factors*

---

**Description**

Factors to convert from practical to absolute salinity and vice versa.

**Usage**

```
sw_sfac
```

**Format**

A list with the following:

**longs** the longitude, a vector with 91 elements, range (0,360), third dimension in `del_sa`,

**lats** the latitude, second dimension in `del_sa`, a vector with 44 elements, range (-82,90),

**p** dbar, the first dimension in `del_sa`, a vector with 45 elements, range(0,6131),

**ndepth** the number of depth intervals at a certain lat,long, a matrix of dimension (4,91),

**del\_sa** the salinity anomaly, an array with dimension (45,44,91), i.e. for (p, lats, longs) values.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Millero FJ, Feistel R, Wright DG and McDougall TJ, 2008. The composition of Standard Seawater and the definition of the Reference-Composition Salinity Scale, *Deep-Sea Res. I*, 55, 50-72.

McDougall TJ, Jackett DR and Millero FJ, 2009. An algorithm for estimating Absolute Salinity in the global ocean. *Ocean Science Discussions* 6, 215-242. <http://www.ocean-sci-discuss.net/6/215/2009/>

Uses the Fortran code written by David Jackett <http://www.marine.csiro.au/~jackett/TEOS-10/>



**See Also**

[convert\\_PStoAS](#), to convert from practical salinity to absolute salinity

[convert\\_AStoPS](#), to convert from absolute salinity to practical salinity

**Examples**

```
mf <- par(mfrow = c(2, 1))
ma <- par(mar = c(3, 5, 2, 5))

dsal <- t(sw_sfac$del_sa[1, , ])
dsal [dsal < -90] <- NA
image(sw_sfac$longs, sw_sfac$lats, dsal, col = femmecol(100),
      asp = TRUE, xlab = "dg", ylab = "dg",
      main = "salinity conversion - p = 0 bar")
contour(sw_sfac$longs, sw_sfac$lats, dsal, asp = TRUE, add = TRUE)

dsal <- t(sw_sfac$del_sa[5, ,]) # 5th depth level sw_sfac$p[5]
dsal [dsal < -90] <- NA
image(sw_sfac$longs, sw_sfac$lats, dsal, col = femmecol(100),
      asp = TRUE, xlab = "dg", ylab = "dg",
      main = "salinity conversion - p = 4 bar")
contour(sw_sfac$longs, sw_sfac$lats, dsal, asp = TRUE, add = TRUE)

par("mfrow" = mf)
par("mar" = ma)
```

---

sw\_svel

*Velocity of the Sound in Seawater*


---

**Description**

Computes the velocity of the sound in seawater, using the UNESCO 1983 polynomial or based on the Gibbs function.

Valid for salinity from 0 to 40, temperature from 0 to 40 dgC, pressure from 1 to 1000 bars.

**Usage**

```
sw_svel(S = 35, t = 25, p = P-1.013253, P = 1.013253,
        method = c("Gibbs", "UNESCO"))
```

**Arguments**

S	Salinity, when method = "UNESCO": practical salinity (-) else absolute salinity (g/kg),
t	Temperature, °C,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar

P true pressure, bar  
 method When "UNESCO", uses the UNESCO (1983) polynomial, when "Gibbs", based on the gibbs functions as in Feistel, 2008

### Value

Sound velocity, in m / sec.

### Note

Sound velocity for S = 40, t = 40, p = 1000 is 1731.995 using UNESCO polynomial.

### Author(s)

Karline Soetaert <karline.soetaert@nioz.nl>

### References

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.

<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

Feistel R, 2008. A Gibbs function for seawater thermodynamics for -6 to 80 dgC and salinity up to 120 g/kg. Deep-Sea Research I, 55, 1639-1671.

McDougall TJ, Feistel R, Millero FJ, Jackett DR, Wright DG, King BA, Marion GM, Chen C-T A and Spitzer P, 2009. Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134.

### See Also

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sf](#), [sw\\_tfreeze](#), [sw\\_tpot](#)

[convert\\_PStoAS](#), to convert from practical salinity (-) to absolute salinity (g/kg)

[convert\\_AStoPS](#), to convert from absolute salinity (g/kg) to practical salinity (-)

### Examples

```
sw_svel(t = 40, S = 40, p = 10:20, method = "UNESCO")

# Check value UNESCO
sw_svel(t = 40, S = 40, p = 1000, method = "UNESCO") # 1731.995
sw_svel(t = 0, S = 40, p = 0, method = "UNESCO") # 1455.8

sw_svel(t = 40, S = 25, p = 1000, method = "UNESCO") # 1719.2
sw_svel(t = 40, S = 25, p = 0, method = "UNESCO") # 1553.4
sw_svel(t = 0, S = 25, p = 0, method = "UNESCO") # 1435.8

# Check value Gibbs
sw_svel(S = 35.7, t = 25.5, p = 102.3) # 1552.93372863425
```

---

`sw_tfreeze`*Freezing Temperature of Seawater*

---

**Description**

Estimates the freezing temperature of seawater, using the UNESCO 1983 polynomial.

Valid for salinity 4-40

**Usage**

```
sw_tfreeze(S=35, p = P-1.013253, P = 1.013253 )
```

**Arguments**

S	practical salinity, -,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
P	true pressure, bar

**Value**

Temperature, °C

**Note**

freezing temperature for S = 40, p = 50 is -2.588567 dgC.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.  
<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#),  
[sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfacs](#), [sw\\_svel](#), [sw\\_tpot](#)

**Examples**

```
sw_tfreeze(S = 40,p = 50)

## Check values
sw_tfreeze(S = 10,p = 0) #-0.542
sw_tfreeze(S = 10,p = 10) #-0.618
sw_tfreeze(S = 30,p = 0) #-1.638
sw_tfreeze(S = 40,p = 50) #-2.589
```

sw\_tpot

*Potential Temperature of Seawater***Description**

Estimates the potential temperature of seawater, using the UNESCO 1983 polynomial.

It is the temperature an element of seawater would have if raised adiabatically with no change of salinity, to atmospheric pressure.

**Usage**

```
sw_tpot(S = 35, t = 25, p, pref = 0)
```

**Arguments**

t	temperature, °C,
S	practical salinity, -,
p	gauge or applied pressure, pressure referenced against the local atmospheric pressure, bar
pref	reference hydrostatic pressure, bar.

**Value**

Temperature, °C.

**Note**

sw\_tpot for S = 40, t = 40, p = 1000 is 36.89073 dgC

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Fofonoff NP and Millard RC Jr, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science, 44, 53 pp.

<http://unesdoc.unesco.org/images/0005/000598/059832EB.pdf>

**See Also**

[sw\\_adtgrad](#), [sw\\_alpha](#), [sw\\_beta](#), [sw\\_comp](#), [sw\\_conserv](#), [sw\\_cp](#), [sw\\_dens](#), [sw\\_depth](#), [sw\\_enthalpy](#), [sw\\_entropy](#), [sw\\_gibbs](#), [sw\\_kappa](#), [sw\\_kappa\\_t](#), [sw\\_sfac](#), [sw\\_svel](#), [sw\\_tfreeze](#)

**Examples**

```
sw_tpot(S = 40, t = 40:45, p = 1000)

## check values
sw_tpot(S = 25, t = 40, p = 0)      #40
sw_tpot(S = 25, t = 40, p = 100)   #36.6921
sw_tpot(S = 25, t = 10, p = 1000)  #8.4684
sw_tpot(S = 25, t = 0, p = 100)    #-0.0265

sw_tpot(S = 40, t = 40, p = 1000)  #36.89073
```

vapor

*Saturation Water Vapor Pressure***Description**

The partial pressure of water in saturated air (pH<sub>2</sub>O/P), as in Weiss and Price (1980), where P is the total atmospheric pressure, (1 atmosphere), and pH<sub>2</sub>O is the partial pressure of the water vapor.

**Usage**

```
vapor(S = 35, t = 25)
```

**Arguments**

S	Salinity (-),
t	Temperature, °C.

**Value**

The saturation vapor pressure (-).

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Sarmiento JL and Gruber N, 2006. Ocean Biogeochemical Dynamics. Princeton University Press, Princeton. p 74

Weiss R and Price BA, 1980. Nitrous oxide solubility in water and seawater. Mar. Chem. 8, 347-359.

**See Also**

[gas\\_02sat](#), [gas\\_satconc](#), [gas\\_schmidt](#), [gas\\_solubility](#), [gas\\_transfer](#), [atmComp](#)

**Examples**

```
plot(0:30, vapor(t = 0:30), xlab = "Temperature, dgC", ylab = "pH2O/P")
```

---

vapor.hPa

*Vapor Pressure*

---

**Description**

The vapor pressure of water, in hPa.

**Usage**

```
vapor.hPa(t = 25)
```

**Arguments**

t                    Temperature, °C.

**Value**

The vapor pressure of water, in hecto Pascal; valid for temperature of [-50,100] dgC.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>, Lorenz Meire <lorenz.meire@nioz.nl>

**References**

Lowe, P.R. and J.M. Ficke, 1974: The computation of saturation vapor pressure. Tech. Paper No. 4-74, Environmental Prediction Research Facility, Naval Postgraduate School, Monterey, CA, 27 pp.

<http://www.cactus2000.de/uk/unit/masshum.shtml>

**See Also**

[vapor](#), [air\\_spechum](#), [air\\_density](#), [gas\\_02sat](#), [gas\\_satconc](#), [gas\\_schmidt](#), [gas\\_solubility](#), [gas\\_transfer](#), [atmComp](#)

**Examples**

```
vapor.hPa(t = 25)
plot(0:30, vapor.hPa(t = 0:30), xlab = "Temperature, dgC", ylab = "hPa")
```

---

vertmean	<i>Vertical Volume Weighted Mean of Matter Concentrations in Water Bodies</i>
----------	---

---

**Description**

Calculate vertical mean values which respect to depths of different layers or lake morphometry.

**Usage**

```
vertmean(depth, vari, level, top, bot, vol, total=FALSE)
```

**Arguments**

depth	sorted vector of sampled depths,
vari	measurements corresponding to depth (concentration, temperature, ...),
level	surface water level (above ground or above sea level (m a.s.l.), depending on bathymetric function used,
top	top water level of requested layer over which to average or integrate,
bot	bottom water level of requested layer over which to average or integrate,
vol	hypsographic function to be used (e.g. vol.depth),
total	if TRUE the total sum over the water body is returned (integrated value), instead of the volumetric mean.

**Value**

Volumetric average respectively total value (for total =TRUE) for a given quantity (concentration, energy, temperature) in the requested layer between depths top and bottom.

**Author(s)**

Thomas Petzoldt

**See Also**

[coriolis](#), [viscosity](#), [diffcoeff](#), [ssd2rad](#), [gravity](#)

**Examples**

```
## define a bathymetric formula for a given lake or basin
## z:   water depth (m below surface)
## zz:  water column (m above ground)
## level: total water depth (m above ground or above reference level)
weight.vol <- function(z, level) {
  zz <- level - z
  if (any(zz < 0)) stop("depth > maximum depth")
}
```

```

    vol <- 175947 * zz^2 + 2686 * zz^3 # m^3
  }

  ## area is first derivative
  area <- function(z, level) {
    zz <- level - z
    A <- 0.5 * 175947 * zz + 1/3 * 2686 * zz^2 # m^2
  }

  ## dummy formula for depth-weighted averaging
  ## (water column, instead of bathymetric curve)
  weight.column <- function(z, level) {z}

  ## Plot of lake volume (bathymetric curve)
  par(mfrow = c(1, 2))
  z <- 0:12
  V <- weight.vol(z, 12)
  plot(V, z, type = "l", ylim = c(12, 0), xlab = "Volume (m3)",
       ylab = "Depth (m)")
  polygon(c(V, 0), c(z, 0), col = "cyan")

  ## Test Data
  level <- 12
  depth <- c(0, 1, 3.5, 5, 7, 10, 10.5, 11.5)
  pconc <- c(3.7, 4.2, 6.1, 8.9, 7.8, 9.7, 11.4, 11.4)

  ## Plot test data
  plot(pconc, depth, xlim=range(c(0, pconc)), ylim=c(12,0), type="n",
       xlab="P concentration (mu g / L)", ylab="Depth (m)")
  segments(rep(0, 13), depth, pconc, depth, lwd=3)

  ## simple means
  m <- mean(pconc[depth <= 4])
  lines(c(m, m), c(0, 4), col="blue", lwd=2)

  m <- mean(pconc[depth >= 4])
  lines(c(m, m), c(4, 12), col="blue", lwd=2)

  ## depth weighted
  m <- vertmean(depth, pconc, level, top=0, bot=4, weight.column)
  lines(c(m, m), c(0, 4), col="red", lwd=2)

  m <- vertmean(depth, pconc, level, top=4, bot=12, weight.column)
  lines(c(m, m), c(4, 12), col="red", lwd=2)

  ## volume weighted
  m <- vertmean(depth, pconc, level, top=0, bot=4, weight.vol)
  lines(c(m, m), c(0, 4), col="green", lwd=2)

  m <- vertmean(depth, pconc, level, top=4, bot=12, weight.vol)
  lines(c(m, m), c(4, 12), col="green", lwd=2)

  m <- vertmean(depth, pconc, level, top=4, bot=12, weight.vol)

```



```

lines(c(m, m), c(4, 12), col="green", lwd=2)

legend("topright", col=c("blue", "red", "green"), lwd=2, cex=0.7,
      legend=c("non weighted", "depth weighted", "volume weighted"))

## total sum over the whole water column
vertmean(depth, pconc, level, top=0, bot=12, weight.vol, total=TRUE)

```

viscosity

*Shear Viscosity of Water***Description**

Calculates the shear viscosity of water, in centipoise (g/m/sec). Valid for  $0 < t < 30$  °C,  $0 < S < 36$ ,  $1 < P < 1000$  bars.

Based on the code "CANDI" by B.P. Boudreau

**Usage**

```
viscosity(S = 35, t = 25, P = 1.013253)
```

**Arguments**

S	salinity, -
t	temperature, °C,
P	True pressure, bar.

**Details**

The details given in the original code by B. Boudreau are repeated here:

Uses the equation given by Kukulka et al. (1987).

**Value**

Shear viscosity in centipoise.

**Author(s)**

Karline Soetaert <karline.soetaert@nioz.nl>

**References**

Based on the FORTRAN implementation of the diagenetic model "CANDI" of B.P. Boudreau:

Boudreau BP, 1996. A method-of-lines code for carbon and nutrient diagenesis in aquatic sediments. *Computers & Geosciences* 22 (5), 479-496.

Kulkula DJ, Gebhart B and Mollendorf JC, 1987. Thermodynamic and transport properties of pure and saline water. *Adv. Heat transfer* 18, 325-363.

**See Also**

[coriolis](#), [diffcoeff](#), [ssd2rad](#), [vertmean](#), [gravity](#)

**Examples**

```
plot(0:30, viscosity(t = 0:30, S = 35, P = 1),
     xlab = "temperature", ylab = "g/m/s",
     main = "shear viscosity of water", type = "l")
lines(0:30, viscosity(t = 0:30, S = 0, P = 1), col = "red")
lines(0:30, viscosity(t = 0:30, S = 35, P = 100), col = "blue")
legend("topright", col = c("black", "red", "blue"), lty = 1,
      legend = c("S=35, P=1", "S=0, P=1", "S=35, P=100"))
```

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