

Package ‘iapws’

August 10, 2022

Type Package

Title Formulations of International Association for the Properties of Water and Steam

Version 0.7

Date 2022-08-05

Depends R (>= 3.3.1)

Description Implementation of some of the formulations for the thermodynamic and transport properties of ordinary water and steam released by the International Association for the Properties of Water and Steam (IAPWS). More specifically, the releases referenced R6-95(2018), R7-97(2012), R12-08 and R15-11 at <<http://iapws.org/release.html>>.

License GPL (>= 3)

NeedsCompilation yes

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Repository CRAN

Date/Publication 2022-08-10 14:30:06 UTC

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iapws95

*IAPWS Formulation 1995 in the Single Phase Regions***Description**

Compute thermodynamic and transport properties of water and steam using the IAPWS formulation 1995.

Usage

```
iapws95(what, rho, t)
iapws95_pt(what, p, t, state = iapws95_state(p, t))
```

Arguments

what	a character vector listing the output properties. See Details for available properties.
rho	a numeric vector giving the values of density in kg/m ³ .
t	a numeric vector giving the temperature values in K.
p	a numeric vector giving the pressure values in MPa.
state	a character vector giving the physical state. One of "liquid", "gas" or "supercritical".

Details

The currently available properties are:

- "f": the specific free energy in kJ/kg.
- "g": the specific Gibbs enthalpy in kJ/kg.
- "u": the specific internal energy in kJ/kg.
- "h": the specific enthalpy in kJ/kg.
- "s": the specific entropy in kJ/K/kg.
- "t": the temperature in K.
- "p": the pressure in MPa.
- "v": the specific volume in m³/kg.
- "rho": the mass density in kg/m³.
- "cv": the specific isochoric heat capacity in kJ/K/kg.
- "cp": the specific isobaric heat capacity in kJ/K/kg.
- "alpha": the expansion coefficient in 1/K
- "beta": the pressure coefficient in MPa/K.
- "chi t": the isothermal compressibility in 1/MPa.
- "w": the speed of sound in m/s.
- "eta": the dynamic viscosity in 10⁻⁶Pa.s.
- "lambda": the thermal conductivity in mW/K/m.

Value

A numeric matrix of dimension $c(n, \text{length}(\text{what}))$ with n the maximum length of either ρ , p , t or state .

Note

Computing the needed properties simultaneously (in a single call) should be more efficient than separately because most of the computation is shared between the different properties.

Author(s)

Jonathan Debove

References

International Association for the Properties of Water and Steam, IAPWS R6-95(2018), Revised Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use.

International Association for the Properties of Water and Steam, IAPWS R12-08(2008), Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance.

International Association for the Properties of Water and Steam, IAPWS R15-11(2011), Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance.

Examples

```
# IAPWS95
format(iapws95(c("p", "cv", "w", "s"),
  t = c(300, 300, 300,
    500, 500, 500, 500,
    647,
    900, 900, 900),
  rho = c(0.9965560e3, 0.1005308e4, 0.1188202e4,
    0.4350000e0, 0.4532000e1, 0.8380250e3, 0.1084564e4,
    0.3580000e3,
    0.2410000e0, 0.5261500e2, 0.8707690e3)),
  scientific = TRUE, digits = 9)

# Viscosity
format(iapws95("eta",
  t = c(298.15, 298.15, 373.15,
    433.15, 433.15,
    873.15, 873.15, 873.15,
    1173.15, 1173.15, 1173.15),
  rho = c(998, 1200, 1000,
    1, 1000,
    1, 100, 600,
    1, 100, 400)),
  digits = 8)
format(iapws95("eta", t = 647.35,
  rho = c(122, 222, 272, 322, 372, 422)),
```

```

        digits = 8)

# Thermal conductivity
format(iapws95("lambda",
  t = c(298.15, 298.15, 298.15, 873.15),
  rho = c(0, 998, 1200, 0)),
  digits = 9)
format(iapws95("lambda", t = 647.35,
  rho = c(1, 122, 222, 272, 322, 372, 422, 750)),
  digits = 9)

```

iapws95_sat

IAPWS Formulation 1995 in the Saturation Region

Description

Compute thermodynamic and transport properties of water and steam along the saturated line according to the IAPWS formulation 1995.

Usage

```

iapws95_sat(what, t)
iapws95_sat_p(what, p)

```

Arguments

what	a character vector listing the output properties. See Details for available properties.
t	a numeric vector giving the temperature values in K.
p	a numeric vector giving the pressure values in MPa.

Details

The currently available properties are:

- "f": the specific free energy in kJ/kg.
- "g": the specific Gibbs enthalpy in kJ/kg.
- "u": the specific internal energy in kJ/kg.
- "h": the specific enthalpy in kJ/kg.
- "s": the specific entropy in kJ/K/kg.
- "t": the temperature in K.
- "p": the pressure in MPa.
- "v": the specific volume in m³/kg.
- "rho": the mass density in kg/m³.
- "cv": the specific isochoric heat capacity in kJ/K/kg.

- "cp": the specific isobaric heat capacity in kJ/K/kg.
- "alpha": the expansion coefficient in 1/K
- "beta": the pressure coefficient in MPa/K.
- "chit": the isothermal compressibility in 1/MPa.
- "w": the speed of sound in m/s.
- "eta": the dynamic viscosity in 10^{-6} Pa.s.
- "lambda": the thermal conductivity in mW/K/m.

Value

A numeric array of dimension $c(n, \text{length}(\text{what}), 2L)$ with n the length of either p or t . The last dimension indicate the physical state (liquid or gas).

Note

Computing the needed properties simultaneously (in a single call) should be more efficient than separately because most of the computation is shared between the different properties.

Author(s)

Jonathan Debove

References

International Association for the Properties of Water and Steam, IAPWS R6-95(2018), Revised Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use.

Examples

```
format(iapws95_sat(c("p", "rho", "h", "s"), t = c(275, 450, 625)),  
       scientific = TRUE, digits = 9)
```

iapws95_state

IAPWS Formulation 1995 Physical State

Description

Compute the physical state of water according the IAPWS formulation 1995.

Usage

```
iapws95_state(p, t)
```

Arguments

p	a numeric vector giving the pressure values in MPa.
t	a numeric vector giving the temperature values in K.

Value

A character vector giving the physical state. One of "solid", "liquid", "gas", "supercritical" or "undef".

Author(s)

Jonathan Debove

Examples

```
iapws95_state(.1, 293.15)
iapws95_state(.1, 373.15)
iapws95_state(23, 650)
```

 if97

IAPWS-IF97 Basic Equations for Regions 1, 2, 3 and 5

Description

Compute thermodynamic and transport properties of water and steam using the IAPWS industrial formulation 1997.

Usage

```
if97(what, p, t, state = if97_state(p, t))
```

Arguments

what	a character vector listing the output properties. See Details for available properties.
p	a numeric vector giving the pressure values in MPa.
t	a numeric vector giving the temperature values in K.
state	a character vector giving the physical state. One of "liquid", "gas" or "supercritical".

Details

The currently available properties are:

- "f": the specific free energy in kJ/kg.
- "g": the specific Gibbs enthalpy in kJ/kg.
- "u": the specific internal energy in kJ/kg.
- "h": the specific enthalpy in kJ/kg.
- "s": the specific entropy in kJ/K/kg.
- "t": the temperature in K.
- "p": the pressure in MPa.
- "v": the specific volume in m³/kg.
- "rho": the mass density in kg/m³.
- "cv": the specific isochoric heat capacity in kJ/K/kg.
- "cp": the specific isobaric heat capacity in kJ/K/kg.
- "alpha": the expansion coefficient in 1/K
- "beta": the pressure coefficient in MPa/K.
- "chit": the isothermal compressibility in 1/MPa.
- "w": the speed of sound in m/s.
- "eta": the dynamic viscosity in 10⁻⁶Pa.s.
- "lambda": the thermal conductivity in mW/K/m.

Value

A numeric matrix of dimension c(n, length(what)) with n the maximum length of either p, t or state.

Note

Computing the needed properties simultaneously (in a single call) should be more efficient than separately because most of the computation is shared between the different properties.

Author(s)

Jonathan Debove

References

International Association for the Properties of Water and Steam, IAPWS R7-97(2012), Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam.

International Association for the Properties of Water and Steam, IAPWS R12-08(2008), Release on the IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance.

International Association for the Properties of Water and Steam, IAPWS R15-11(2011), Release on the IAPWS Formulation 2011 for the Thermal Conductivity of Ordinary Water Substance.

Examples

```

what <- c("v", "h", "u", "s", "cp", "w")

# Region 1
format(if97(what, t = c(300, 300, 500), p = c(3, 80, 3)),
       scientific = TRUE, digits = 9)

# Region 2
format(if97(what, t = c(300, 700, 700), p = c(3.5e-3, 3.5e-3, 30)),
       scientific = TRUE, digits = 9)

# Region 2 metastable
format(if97(what, t = c(450, 440, 450), p = c(1, 1, 1.5), state = "gas"),
       scientific = TRUE, digits = 9)

# Region 3
format(if97(what, t = c(650, 650, 750),
           p = c(0.255837018e2, 0.222930643e2, 0.783095639e2)),
       scientific = TRUE, digits = 9)

# Region 5
format(if97(what, t = c(1500, 1500, 2000), p = c(0.5, 30, 30)),
       scientific = TRUE, digits = 9)

# Viscosity and thermal conductivity
what <- c("lambda", "eta")
## Region 1
format(if97(what, p = c(20, 50), t = c(620, 620)),
       scientific = TRUE, digits = 9)

## Region 2
format(if97(what, p = c(0.3, 50), t = c(650, 800)),
       scientific = TRUE, digits = 9)

## Region 3
#format(if97_rhot(c("lambda", "rho", "cp", "cv", "eta"),
#               rho = c(0.3, 50), t = c(222, 322)),
#       scientific = TRUE, digits = 9)

```

if97_psat

IAPWS-IF97 Equations in Region 4

Description

Compute the pressure and the temperature along the saturated line according to the IAPWS industrial formulation 1997.

Usage

```

if97_psat(t)
if97_tsat(p)

```


Arguments

t a numeric vector giving the temperature values in K.
 p a numeric vector giving the pressure values in MPa.

Value

A numeric vector containing the saturation-pressure (MPa) or the saturation-temperature (K). Return 0 for inputs outside of the range of validity.

Author(s)

Jonathan Debove

References

International Association for the Properties of Water and Steam, IAPWS R7-97(2012), Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam.

Examples

```
# Region 4
format(if97_psat(t = c(300, 500, 600)), scientific = TRUE, digits = 9)
format(if97_tsat(p = c(0.1, 1.0, 10.0)), scientific = TRUE, digits = 9)
```

if97_state	<i>IAPWS-IF97 Physical State</i>
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Description

Compute the physical state of water according the IAPWS industrial formulation 1997.

Usage

```
if97_state(p, t)
```

Arguments

p a numeric vector giving the pressure values in MPa.
 t a numeric vector giving the temperature values in K.

Value

A character vector giving the physical state. One of "solid", "liquid", "gas", "supercritical" or "undef".

Author(s)

Jonathan Debove

Examples

```
if97_state(.1, 293.15)  
if97_state(.1, 373.15)  
if97_state(23, 650)
```

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