

# Property Library for Carbon Dioxide

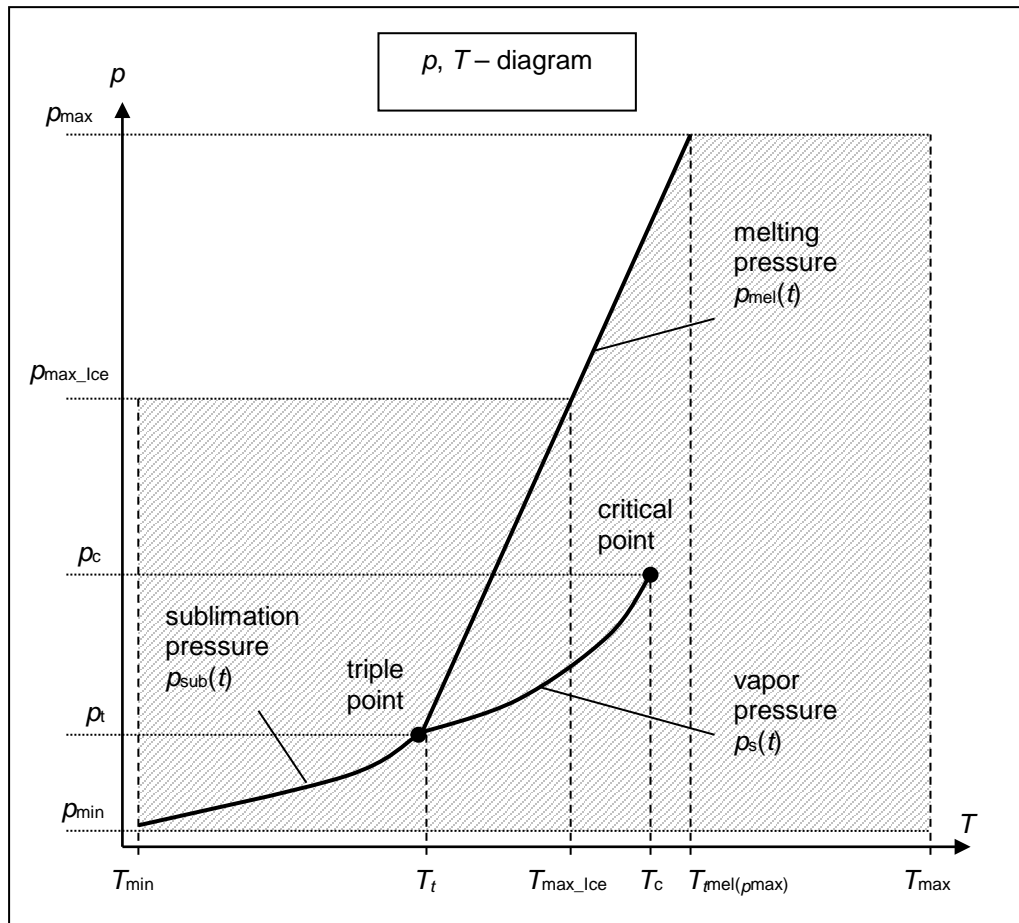
## LibCO2

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## Property Functions

**Units:**  $t$  in °C  
 $p$  in bar  
 $x$  in kg /kg (Phase fraction, see the following explanations)

**Range of Validity:**



**Reference State:**

At  $p = 1.01325$  bar and  $T = 298.15$  K (25 °C) :  
 $h = -0.938457860$  kJ/kg and  $s = -0.00219606205$  kJ/(kg K)

Factor	Abbreviation	Value and Unit
Minimum temperature	$T_{\min} (t_{\min})$	85 K (-188.15 °C)
Maximum temperature	$T_{\max} (t_{\max})$	1500 K (1226.85 °C)
Triple temperature	$T_t (t_t)$	216.592 K (-56.558 °C)
Temperature at the critical point	$T_c (t_c)$	304.1282 K (30.9782 °C)
Maximum temperature of solid region	$T_{\max\_Ice} (t_{\max\_Ice})$	236.0309 K (-37.119 °C)
Maximum temperature of melting pressure curve	$T_{\text{mel}}(p_{\max}) (t_{\text{mel}}(p_{\max}))$	327.671 K (54.521 °C)
Minimum pressure	$p_{\min} = p_{\text{sub}}(T_{\min})$	$2.9081875815 \cdot 10^{-10}$ bar
Maximum pressure	$p_{\max}$	8000 bar
Triple pressure	$p_t$	5.179618369088 bar
Pressure at the critical point	$p_c$	73.773 bar
Maximum pressure of solid region	$p_{\max\_Ice}$	1000 bar

### General Property Functions

Functional Dependence	Function Name	Call from Fortran program	Property or Function	Unit of the Result
$a = f(p, t, x)$	a_ptx_CO2	APTXXCO2(P,T,X)	Thermal diffusivity	m <sup>2</sup> /s
$c_p = f(p, t, x)$	cp_ptx_CO2	CPPTXXCO2(P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p, t, x)$	cv_ptx_CO2	CVPTXXCO2(P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\eta = f(p, t, x)$	eta_ptx_CO2	ETAPTXXCO2(P,T,X)	Dynamic viscosity	Pa s
$h = f(p, t, x)$	h_ptx_CO2	HPTXXCO2(P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p, t, x)$	kappa_ptx_CO2	KAPTXXCO2(P,T,X)	Isentropic exponent	-
$\lambda = f(p, t, x)$	lambda_ptx_CO2	LAMPTXXCO2(P,T,X)	Thermal conductivity	W/(m K)
$\nu = f(p, t, x)$	ny_ptx_CO2	NYPTXXCO2(P,T,X)	Kinematic viscosity	m <sup>2</sup> /s
$p_{\text{mel}} = f(t)$	pmel_t_CO2	PMELCO2(T)	Melting pressure from temperature	bar
$p_{\text{sub}} = f(t)$	psub_t_CO2	PSUBCO2(T)	Sublimation pressure from temperature	bar
$p_s = f(t)$	ps_t_CO2	PSTCO2(T)	Vapor pressure from temperature	bar
$Pr = f(p, t, x)$	Pr_ptx_CO2	PRPTXXCO2(P,T,X)	<i>Prandtl</i> -Number	-
$\rho = f(p, t, x)$	rho_ptx_CO2	ROPTXXCO2(P,T,X)	Density	kg/ m <sup>3</sup>
$s = f(p, t, x)$	s_ptx_CO2	SPTXXCO2(P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p, h)$	t_ph_CO2	TPHCO2(P,H)	Backward function: Temperature from pressure and enthalpy	°C

Functional Dependence	Function Name	Call from Fortran program	Property or Function	Unit of the Result
$t = f(p, s)$	t_ps_CO2	TPSCO2(P,S)	Backward function: Temperature from pressure and entropy	°C
$t_{\text{mel}} = f(p)$	tmel_p_CO2	TMELCO2(P)	Melting temperature from pressure	°C
$t_{\text{sub}} = f(p)$	tsub_p_CO2	TSUBCO2(P)	Sublimation temperature from pressure	°C
$t_{\text{s}} = f(p)$	ts_p_CO2	TSPCO2(P)	Saturation temperature from pressure	°C
$v = f(p, t, x)$	v_ptx_CO2	VPTXCO2(P,T,X)	Specific volume	m <sup>3</sup> /kg
$w = f(p, t, x)$	w_ptx_CO2	WPTXCO2(P,T,X)	Isentropic speed of sound	m/s
$x = f(p, h)$	x_ph_CO2	XPHCO2(P,H)	Backward function: Phase fraction from pressure and enthalpy	kg/kg
$x = f(p, s)$	x_ps_CO2	XPSCO2(P,S)	Backward function: Phase fraction from pressure and entropy	kg/kg
$z = f(p, t, x)$	z_ptx_CO2	ZPTXCO2(P,T,X)	Compression factor	-

### Property Functions for Solid Carbon Dioxide (Dry Ice)

Functional Dependence	Function Name	Call from Fortran program	Call from the DLL LibCO2 as Parameter	Property or Function	Unit of the Result
$a = f(p, t)$	aICE_pt_CO2	APICETCO2(P,T)	C_APICEPTCO2 (A, P, T)	Thermal diffusivity	m <sup>2</sup> /s
$c_p = f(p, t)$	cpICE_pt_CO2	CPICETCO2(P,T)	C_CPICEPTCO2 (CP, P, T)	Specific isobaric heat capacity	kJ/(kg K)
$h = f(p, t)$	hICE_pt_CO2	HICETCO2(P,T)	C_HICEPTCO2 (H, P, T)	Specific enthalpy	kJ/ kg
$\lambda = f(t)$	lambdaICE_t_CO2	LAMICETCO2(T)	C_LAMICETCO2 (LAM,T)	Thermal conductivity	W/(m K)

Functional Dependence	Function Name	Call from Fortran program	Call from the DLL LibCO2 as Parameter	Property or Function	Unit of the Result
$\rho = f(p, t)$	rhoICE_pt_CO2	RHOICETCO2(P,T)	C_RHOICEPTCO2 (RHO, P, T)	Density	kg/ m <sup>3</sup>
$s = f(p, t)$	sICE_pt_CO2	SICETCO2(P,T)	C_SICEPTCO2 (S, P, T)	Specific entropy	kJ/ (kg K)
$v = f(p, t)$	vICE_pt_CO2	VICETCO2(P,T)	C_VICEPTCO2 (V, P, T)	Specific volume	m <sup>3</sup> /kg
$t = f(p, h)$	tICE_ph_CO2	TICEHCO2(P,H)	C_TICEPHCO2 (T, P, H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p, s)$	tICE_ps_CO2	TICESCO2(P,S)	C_TICEPSCO2 (T, P, S)	Backward function: Temperature from pressure and entropy	°C

### Details on the Phase Fraction $x$

If the state point to be calculated is located in the single phase region (solid, liquid or superheated vapor),  $x = -1$  must be entered as a pro-forma value. Here the backward functions will also result in  $x = -1$ .

The two phase regions wet vapor region, melting region and sublimation region (cp. the following  $\lg p, h$ -diagram) are calculated automatically by the subprograms. Please consider the following facts:

#### 1. Wet Vapor Region ( $0 \leq x \leq 1$ ):

The phase fraction  $x$  equates to the vapor fraction  $x$  in the wet vapor region in (kg dry saturated vapor)/(kg wet vapor).

In this case it is adequate to enter either the given value for  $t$  and  $p = -1000$ , or the given value for  $p$  and  $t = -1000$ , plus the value for  $x$  between 0 and 1. If values for both  $p$  and  $t$  are entered when calculating wet vapor, the program will consider  $p$  and  $t$  to be appropriate to represent the vapour pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in  $-1000$ .

When calculating wet vapor,  $x$  results in a value between 0 and 1 ( $x = 0$  for boiling liquid,  $x = 1$  for dry saturated vapor). In this case, the backward functions result in the appropriate value between 0 and 1 for  $x$ .

Wet vapor region: Temperature range from  $T_t = 216.592$  K ( $t_t = -56.558$  °C) to  $T_c = 304.1282$  K ( $t_c = 30.9782$  °C)

Pressure ranges from  $p_t = 5.179618369088$  bar to  $p_c = 73.773$  bar

#### 2. Melting Region ( $10 \leq x \leq 11$ ):

The phase fraction  $x$  equates to the liquid fraction  $x$  in the melting region in (kg solidifying liquid)/(kg melt), whereas melt is a mixture of melting solid and

solidifying liquid.

In this case it is adequate to enter either the given value for  $t$  and  $p = -1000$ , or the given value for  $p$  and  $t = -1000$ , plus the value for  $x$  between 10 and 11. If values for both  $p$  and  $t$  are entered, the program will consider  $p$  and  $t$  to be appropriate to represent the melting pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in  $-1000$ .

When calculating a melt,  $x$  results in a value between 10 and 11 ( $x = 10$  for melting solid,  $x = 11$  for solidifying liquid). In this case, the backward functions result in the appropriate value between 10 and 11 for  $x$ .

Melting region: Temperature range from  $T_{\max\_Ice} = 236.0309$  K ( $t_{\max\_Ice} = -37.119$  °C) to  $T_t = 216.592$  K ( $t_t = -56.558$  °C)  
Pressure range from  $p_t = 5.179618369088$  bar to  $p_{\max\_Ice} = 1000$  bar

Only the limiting curve on the right hand side, thus solidifying liquid ( $x = 11$ ) is calculated for pressures  $p$  for which applies  $p_{\max\_Ice} < p \leq p_{\max}$ .

### 3. Sublimation Region ( $100 \leq x \leq 101$ ):

The phase fraction  $x$  equates to the vapor fraction  $x$  in the sublimation region in (kg desublimating vapor)/(kg sublimation powder), whereas sublimation powder is a mixture of sublimating solid and desublimating vapor.

In this case it is adequate to enter either the given value for  $t$  and  $p = -1000$ , or the given value for  $p$  and  $t = -1000$ , plus the value for  $x$  between 100 and 101. If values for both  $p$  and  $t$  are entered, the program will consider  $p$  and  $t$  to be appropriate to represent the sublimation pressure curve. If it is not the case the calculation for the quantity of the chosen function to be calculated results in  $-1000$ .

When calculating sublimation powder,  $x$  takes a value between 100 and 101 ( $x = 100$  for sublimating solid,  $x = 101$  for desublimating vapor). In this case, the backward functions result in the appropriate value between 100 and 101 for  $x$ .

Sublimation region: Temperature range from  $T_{\min} = 85$  K ( $t_{\min} = -188.15$  °C) to  $T_t = 216.592$  K ( $t_t = -56.558$  °C)  
Pressure range from  $p_{\min} = 2.9081875815 \cdot 10^{-10}$  bar to  $p_t = 5.179618369088$  bar

#### Note:

If the input values are located outside the range of validity, the calculated function will always result in  $-1000$ . Please find more exact details on every function and its corresponding range of validity in the enclosed software documentation in Chapter 3. The same information may also be accessed via the online help pages.

