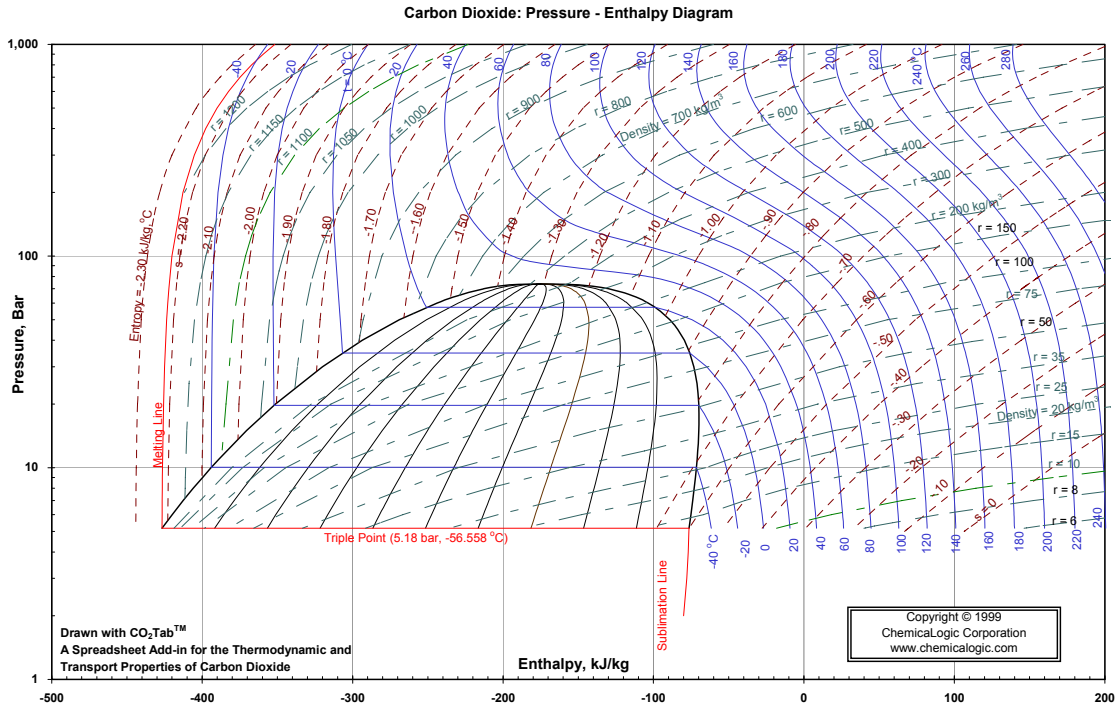
CO_2Tab V2.0 User's Guide

THERMODYNAMIC AND TRANSPORT PROPERTIES OF CARBON DIOXIDE



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ChemicaLogic Corporation, 222 Stoney Gate, Carlisle MA, 01741 USA
Tel: 978-254-1218
www.chemicalogic.com

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CO_2Tab™ Thermodynamic and Transport Properties of Carbon Dioxide

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Chapter 1

Introduction to CO_2Tab

Heredity is a strong factor, even in architecture. Necessity first mothered invention. Now invention has little ones of her own, and they look just like grandma.
– E. B. White (1899–1985), U.S. author, editor.
"The Old and the New," in New Yorker (19 June 1937; repr. in Writings from the New Yorker 1927–1976, ed. by Rebecca M. Dale, 1991).

Overview and Features

CO_2Tab is an important productivity tool for those who are engaged in the ever widening variety of applications of carbon dioxide such as: closed-loop refrigeration, frozen food processing, food preservation and storage, beverage carbonation, brewery operations, supercritical fluid extraction, precision cleaning with carbon dioxide, pipeline engineering, secondary oil recovery, slurry transport, inserting, gas processing, CO_2 scrubbing, or research activities for effective CO_2 sequestration methods to control the green-house gases.

CO_2Tab, designed as an add-in package to popular spreadsheet applications, allows users the convenient access, without leaving the spreadsheet computation environment, to a variety of property values. CO_2Tab contains a comprehensive set of thermodynamic and transport properties applicable over a wide range of conditions, with selected derivative and dimensionless properties.

CO_2Tab also includes functions for obtaining the temperature or pressure along the sublimation line and the melting line. CO_2Tab also allows the calculation of the solubility of CO_2 in water, which is an important parameter in atmospheric chemistry, the beverage industry, etc.

CO_2Tab uses fundamental equations to calculate all properties with no interpolation or curve fits to raw data. CO_2Tab uses the international standard formulation for the thermodynamic and transport properties of carbon dioxide. The references used in CO_2Tab are:

Reference

A New Equation of State for Carbon Dioxide Covering the Fluid Region from the Triple Point Temperature to 1100 K at Pressures up to 800 MPa, R. Span and W. Wagner, J. Phys. Chem. Ref. Data, Vol. 25, No. 6, 1996.

The Solubility of Carbon Dioxide in Water at Low Pressure, John J. Carroll, John D. Slupsky, Alan E. Mather, J. Phu. Chem. Ref. Data, Vol. 20, No. 6, 1991

CO_2Tab functions have a wide range of applicability. Generally, the properties returned by these functions are acceptable within the following ranges:

- Pressure (P, bar): $0 \le P \le 8{,}000$
- Temperature (T, °C): $-73.15 \le T \le 826.85$

The CO_2Tab add-in package is based on a set of 29 core functions that together calculate over 40 thermodynamic and transport properties of carbon dioxide. You can use these functions directly in your spreadsheet or you can use CO_2Tab's easy-to-use dialog boxes to automatically generate the appropriate function call with the correct arguments.

CO_2Tab functions are divided into the following categories:

1. Functions for saturated vapor, liquid or two-phase properties (2 functions)
2. Functions for superheated vapor or subcooled liquid properties (9 functions)
3. Melting and Sublimation Line Functions (4 functions)
4. Solubility in Water (2 functions)
5. Functions for constant carbon dioxide properties (12 functions)

Technical Support and Contact Information

ChemicaLogic offers free technical support with the purchase of CO_2Tab. If you have any problems during installation or use of CO_2Tab, please contact us at one of the addresses listed below.

Before requesting support, it would save both your time and our time if you could first do the following:

- Make sure you have read any relevant portions of the manual
- Isolate the problem to a small test case
- Have the version number of your copy of CO_2Tab ready
- Have the version number of the spreadsheet application and the operating system on which it is installed ready

You can contact us via any of the following paths:

By Telephone:	978-254-1218 (9 AM to 5 PM, EST)
By Email:	clc.support@chemicalogic.com
By Web:	http://www.chemicalogic.com
By Mail:	ChemicaLogic Corporation 222 Stoney Gate Carlisle, Massachusetts 01741 USA

Chapter 2

Getting Started

Idiot box, n:
The part of the envelope that tells a person where to place the stamp when they can't figure it out for themselves.
– Rich Hall, "Sniglets".

Minimum System Requirements

You should not encounter any hardware or software problems in using CO_2Tab on any hardware that has one of the following spreadsheet applications pre-installed:

- Microsoft Excel 2011 for Mac OSX 10.5 or later

CO_2Tab requires about 1,400 kilobytes (1.4 MB) of hard disk space. While CO_2Tab will work with 8 to 16 MB of RAM it is recommended that at least 32 MB of RAM be available.

Installation

CO_2Tab contains an automatic installation program written in the spreadsheet application itself. It is recommended that you use this program to install CO_2Tab on your machine.

Note

Before installing CO_2Tab on your machine, it is a good idea to create a backup copy of the distribution diskette.

Using CO_2Tab

The following sections describe how to access and use the various features of CO_2Tab.

Where is CO_2Tab?

As an add-in package to your spreadsheet application, CO_2Tab quietly becomes a part of your spreadsheet. You only see it when you need to use it. Just to make sure that CO_2Tab is available,

1. Start your spreadsheet application (if you have not already started it)
2. Click on the **Tools** menu. You should see a **CO2Tab** pop-up menu somewhere near the bottom of the **Tools** menu
3. Expand the **CO2Tab** pop-up menu by clicking on it
4. The following figure show what you should see
5. You can also access **CO2Tab** from the **ChemicaLogic** toolbar (shown in the figure)

A pop-up menu (which is also known as a drop-down menu) is a special menu item that displays a sublist of menu items when it is selected.

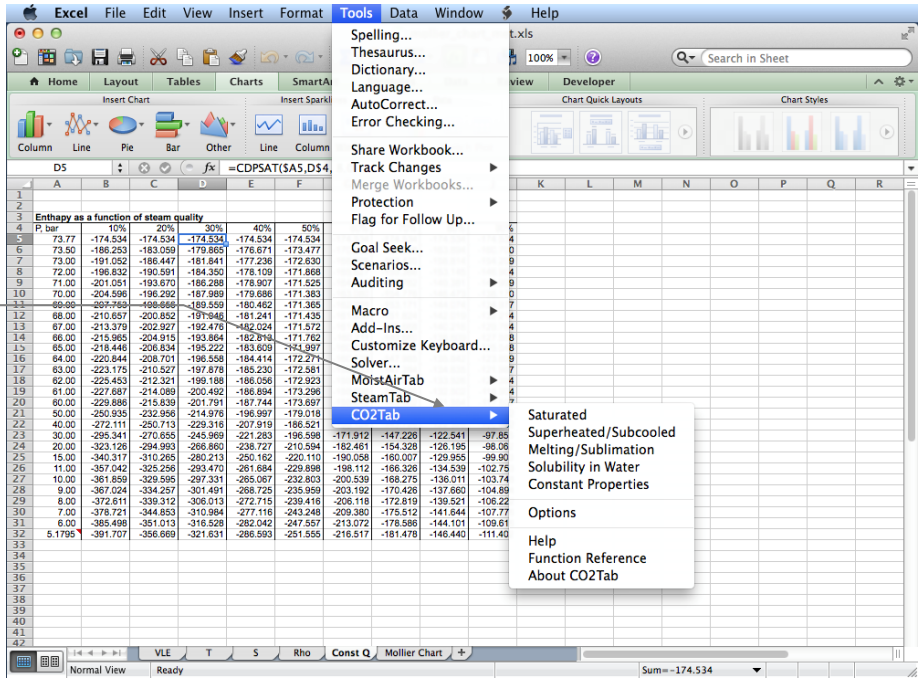


Figure 1: Access to CO_2Tab in Excel

The CO2Tab pop-up menu contains the following menu items:

1. Saturated
   Selecting this menu item brings up the saturated properties dialog box which helps you obtain saturated vapor or liquid properties, or two-phase properties.
2. Superheated/Subcooled
   The menu item displays the dialog box for obtaining supercritical or subcooled properties. This dialog box is also used for constant property processes, such as, isenthalpic, isentropic, constant volume, etc. CO_2Tab uses a highly efficient iterative search algorithm to quickly calculate all constant-process properties.
3. Melting/Sublimation
   This menu item allows you to obtain the melting and sublimation temperature or pressure.
4. Solubility in Water
   This menu item bring up a dialog-box that allows you to calculate the solubility of carbon dioxide in water.
5. Constant Properties
   Selecting this menu item brings up the constant properties dialog box which you can use to select the required constant property.

6. Options
   This menu item allows you to select the units and other configuration options. You can also change the units and interface settings from any of the CO_2Tab dialog-boxes.
7. Help
   Provides you with easy access to online help.
8. About CO2Tab
   Gives you information regarding the version of CO_2Tab installed on your machine.

The following sections describe how to use the various capabilities of CO_2Tab.

Setting CO_2Tab Property Options

The options dialog box helps you in setting up the units to base your property calculations. All of the CO_2Tab dialog-boxes use the same options that you specify from the option dialog box.

If you are using the Worksheet functions directly in you spreadsheet, then you do not have to set the options. The options dialog is only used by the CO_2Tab dialog boxes.

You can access the CO_2Tab options from either the CO2Tab pop-up menu or from any of the other CO_2Tab dialog boxes.

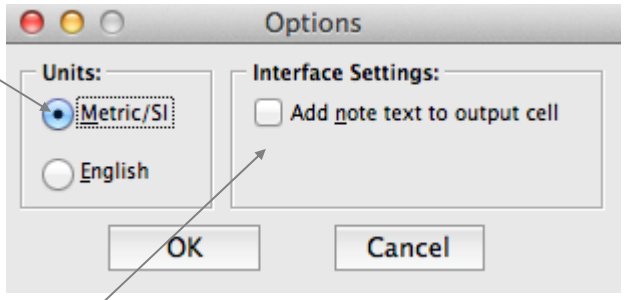
Use the following steps to set the CO_2Tab options (see Figure 2 for an illustration of the CO_2Tab options dialog box):

See Table 1 on page 19 for a listing of carbon dioxide properties and their Metric/SI and English units

1. Select units
   Select the Metric radio button if you want properties in Metric/SI units or select the English radio button for properties English units.
2. Select comment option
   Check the comment box if you want CO_2Tab to place a comment regarding the property calculated and the units in the output cell.
3. Click OK
   Click on the OK button to accept the changes. After you have clicked OK, all of the CO2Tab dialog-boxes will use the specified units options.

> **Note**
>
> If you typically work with only one set of units, you need to only specify them once. CO_2Tab will remember the options in subsequent sessions.

Figure 2: Carbon dioxide Property Options Dialog



Use this group to select the units.

Selecting this option places a note text (or comment text) in the specified output cell showing the name and units of the property calculated. Excel users can view this note by hovering the mouse over this cell.

Using the Saturated Properties Dialog Box

The saturated properties dialog box helps you in calculating saturated vapor or liquid carbon dioxide properties at either specified temperature or specified pressure.

See the Chapter: Function Reference on page 16 for a description of CO_2Tab functions

This dialog box automatically creates a call (with all the correct arguments) to the appropriate CO_2Tab function based on the input parameters you supply.

Use the following steps to calculate a saturated carbon dioxide property (see Figure 3 for an illustration of the saturated carbon dioxide properties dialog box):

1. Select Options (Optional)
   Click on the **Options** button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.
2. Select independent variable
   Choose either **Temperature** or **Pressure** as the independent variable (the variable you wish to specify) by clicking on the appropriate radio button.
3. Provide a value for the independent variable
   Type in a number for the independent variable in the Value edit box. Alternatively, you can type in or select a cell reference that contains a value for the specified independent variable.
4. Select phase
   Select either **Vapor or Liquid** for saturated properties. For two-phase properties, select **Quality** and specify the carbon dioxide quality as a value between 0 and 1.
5. Select carbon dioxide property required
   Using the drop-down combo-box, select the property you want. Use the mouse or the cursor keys to scroll through the list of available carbon dioxide properties until you come to the one you desire.

Depending on your choice of units and independent variable, the value text will show you the units in which the value is required

Tip: Click on a cell where you want the results before opening the saturated dialog box. CO_2Tab will automatically fill in the Output cell reference

6. Provide an output cell reference
   Notice that CO_2Tab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.
7. Click OK
   CO_2Tab will calculate the requested carbon dioxide property and place it in the specified output cell as a formula.

You can determine the triple point and the critical point of carbon dioxide by using the Constant carbon dioxide properties dialog box. See page 12.

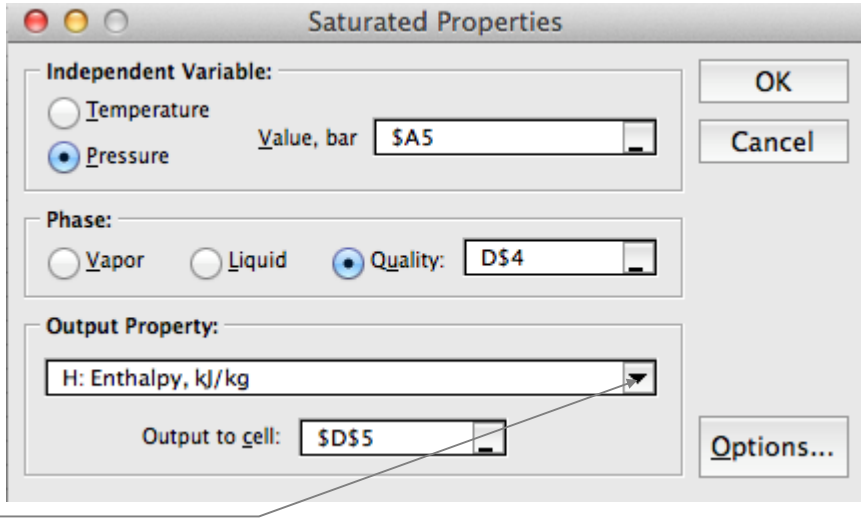
Note

The specified independent variable must be greater or equal to the triple point and less than or equal to the critical point of carbon dioxide. If the specified independent variable is outside these bounds, the CO_2Tab function returns the #VALUE! error.

If you activate the saturated dialog box on a cell that already contains a saturated CO_2Tab function, then CO_2Tab will automatically initialize the dialog box with the correct values.

If you want a different saturated property, simply repeat the above steps. Alternatively, you could copy the cell containing the saturated property function and paste it in the location you want. You can then use the saturated dialog box to change the output carbon dioxide property.

Figure 3: Saturated Properties Dialog



Click here to drop down the list box and to select the desired output carbon dioxide property

Using the Superheated/Subcooled Properties Dialog Box

The superheated/subcooled dialog box helps you in calculating supercritical or subcooled properties. You also use this dialog box to model constant property processes, such as, isenthalpic, isentropic, constant volume, etc.

See the Chapter: Function Reference on page 16 for a description of CO_2Tab functions

Using this dialog box automatically creates a call to the appropriate CO_2Tab function based on the input parameters you supply.

The following steps show you how to use this dialog box (see Figure 4 for an illustration of the superheated/subcooled dialog box):

1. Select Options (Optional)
   Click on the Options button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.
2. Select independent variables
   Unlike saturated properties, calculating superheated or subcooled properties requires two independent variables. CO_2Tab gives you 9 combinations of independent variables that you can choose from:
   Temperature and any one of Pressure, Volume, Enthalpy, Entropy, or Internal energy
   or
   Pressure and any one of Volume, Enthalpy, Entropy, or Internal energy
   a. Select the first independent variable
      Use the drop down list to select either Temperature or Pressure as the first independent variable
   b. Select the second independent variable
      Use the drop down list box to select the second independent variable. The choices available will depend on what you chose as the first independent variable.

Depending on your choice of units and independent variables, the drop-down list box will show you the units in which the values are required

3. Provide values for the independent variables
   Type a number in each of the edit boxes next to the independent variable selections. Alternatively, you can type in or select a cell reference that contains a value for the specified independent variables.
4. Select carbon dioxide property required
   Using the drop-down combo-box, select the property you want. Use the mouse or the cursor keys to scroll through the list of available properties until you come to the one you desire.

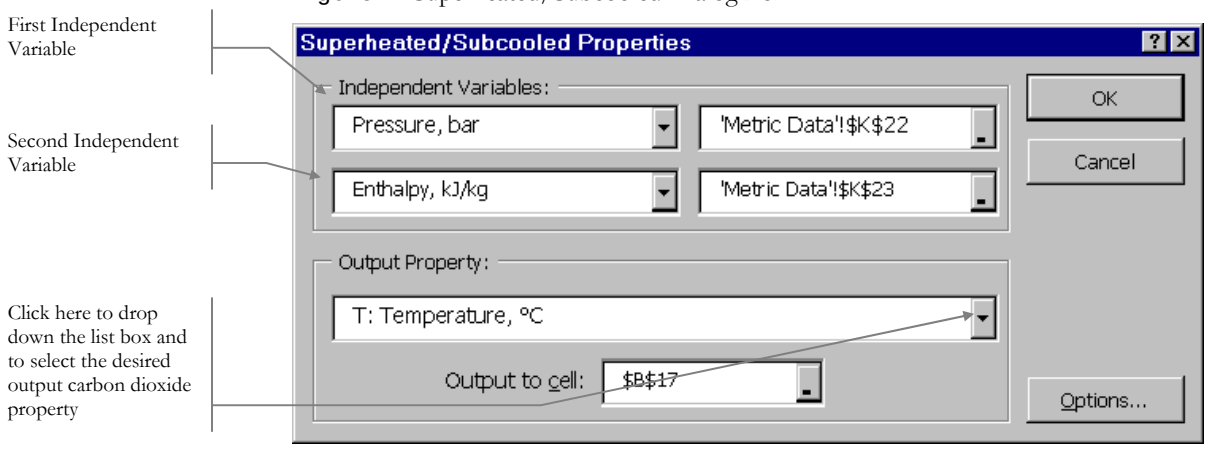
Tip: Click on a cell where you want the results before opening this dialog box. CO_2Tab will automatically fill in the Output cell reference

5. Provide an output cell reference
   Notice that CO_2Tab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.
6. Click OK
   CO_2Tab will calculate the requested property and place it in the specified output cell as a formula.

If you activate the superheated /subcooled dialog box on a cell that already contains a CO_2Tab function, then CO_2Tab will automatically initialize the dialog box with the correct values.

If you want a different superheated or subcooled property, simply repeat the above steps. Alternatively, you could copy the cell containing the superheated/subcooled property function and paste it in the location you want. You can then use the superheated/subcooled dialog box to change the output property.

Figure 4: Superheated/Subcooled Dialog Box



Using the Constant Properties Dialog Box

The constant properties dialog box gives you access to fundamental properties, such as, molecular weight, critical properties, and triple point properties.

The following steps illustrate how to use this dialog box (see the figure below for an illustration of this dialog box):

1. Select Options (Optional)
   Click on the Options button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.
2. Select constant property required
   Using the drop-down combo-box, select the constant property you want. Use the mouse or the cursor keys to scroll through the list of available properties until you come to the one you desire.
3. Provide an output cell reference
   Notice that CO_2Tab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.

Tip: Click on a cell where you want the results before opening this dialog box. CO_2Tab will automatically fill in the Output cell reference

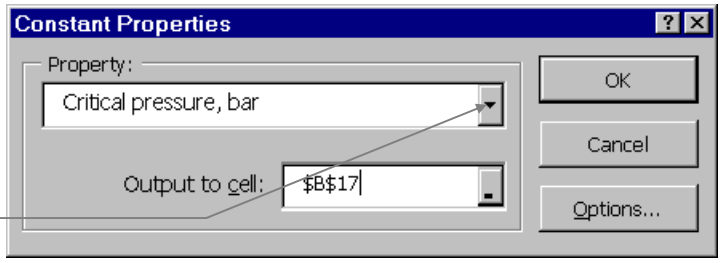
4. Click OK
   CO_2Tab will calculate the requested carbon dioxide property and place it in the specified output cell as a formula.

If you activate the constant property dialog box on a cell that already contains a constant property CO_2Tab function, then CO_2Tab will automatically initialize the dialog box with the correct values.

If you want a different constant property, simply repeat the above steps. Alternatively, you could copy the cell containing the constant property function and paste it in the location you want. You can then use the constant properties dialog box to change the output property.

The following figure illustrates the above steps.

Figure 5: Constant Property Dialog Box



Click here to drop down the list box and to select the desired output carbon dioxide property

Using the Melting/Sublimation Dialog Box

The melting/sublimation property dialog box gives you access to the melting or sublimation pressure or temperature.

The following steps illustrate how to use this dialog box (see the figure below for an illustration of this dialog box):

1. Select Options (Optional)
   Click on the Options button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.
2. Select output property required
   Using the radio buttons, select the desired output property.
3. Provide input data
   Depending on the output property, you will have to give a value or a cell reference containing the value of the input variable.
4. Provide an output cell reference
   Notice that CO_2Tab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.

Tip: Click on a cell where you want the results before opening this dialog box. CO_2Tab will automatically fill in the Output cell reference

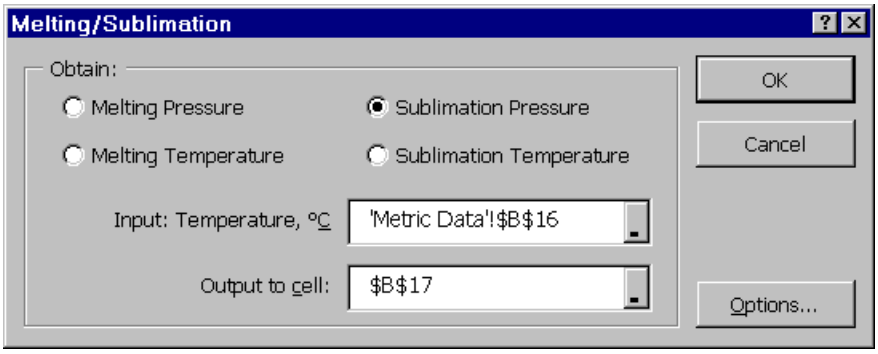
5. Click OK
   CO_2Tab will calculate the requested carbon dioxide property and place it in the specified output cell as a formula.

If you activate the melting / sublimation property dialog box on a cell that already contains a constant property CO_2Tab function, then CO_2Tab will automatically initialize the dialog box with the correct values.

If you want a different property, simply repeat the above steps. Alternatively, you could copy the cell containing the property function and paste it in the location you want. You can then use the properties dialog box to change the output property.

The following figure illustrates the above steps.

Figure 6: Melting/Sublimation Property Dialog Box



Using the Solubility in Water Dialog Box

The solubility in water dialog box gives you access to the molar or mass solubility of carbon dioxide in water.

The following steps illustrate how to use this dialog box (see the figure below for an illustration of this dialog box):

1. Select Options (Optional)
   Click on the Options button to bring up the options dialog-box from where you can select the units, as described in the previous section. If you previously selected the units, you can skip this step.
2. Select Input Data
   Select Temperature and Total Pressure or Temperature and Partial Pressure for your input data and provide the data in the respective edit boxies.
3. Select output property required
   Using the drop-down list, select the output property. You can select either the vapor or liquid mole or mass fractions of carbon dioxide.

Tip: Click on a cell where you want the results before opening this dialog box. CO_2Tab will automatically fill in the Output cell reference

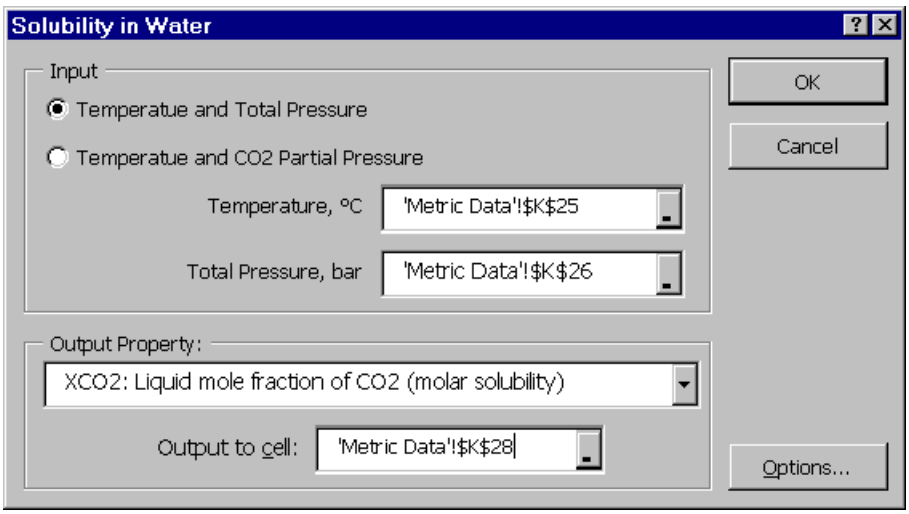
4. Provide an output cell reference
   Notice that CO_2Tab has already filled this in with the currently selected cell reference. If this is not where you want the results to go, select or type in a different cell reference.
5. Click OK
   CO_2Tab will calculate the requested property and place it in the specified output cell as a formula.

If you activate the solubility property dialog box on a cell that already contains a constant property CO_2Tab function, then CO_2Tab will automatically initialize the dialog box with the correct values.

If you want a different property, simply repeat the above steps. Alternatively, you could copy the cell containing the property function and paste it in the location you want. You can then use the properties dialog box to change the output property.

The following figure illustrates the above steps.

Figure 7: Solubility in Water Property Dialog Box



Chapter 3

Function Reference

A triangle which has an angle of 135 degrees is called an obscene triangle.
– FreeBSD fortune cookie.

Overview

The CO_2Tab add-in package is based on a set of 29 core functions that together calculate over 40 thermodynamic and transport properties of carbon dioxide. You can use these functions directly in your spreadsheet or you can use CO_2Tab's easy-to-use dialog boxes to automatically generate the appropriate function call with the correct arguments.

CO_2Tab functions are divided into the following categories:

7. Functions for saturated vapor, liquid or two-phase properties (2 functions)
   These two functions calculate saturated vapor, liquid and two-phase properties from the triple point up to the critical point. You can choose either temperature or pressure as the independent variable.
8. Functions for superheated vapor or subcooled liquid properties (9 functions)
   The functions in this category provide you with a rich set of tools for conducting several constant-property processes. Depending on the choice of independent variables, you can model isentropic, isenthalpic, constant volume, or constant internal energy processes.
9. Melting and Sublimation Line Functions (4 functions)
   The functions in this category calculate the melting and sublimation temperature or pressure.
10. Solubility in Water (2 functions)
    You can obtain the solubility of carbon dioxide in water using the functions provided in this category.

11. Functions for constant carbon dioxide properties (12 functions)

The 12 functions in this category give you access to fundamental carbon dioxide properties that are not functions of temperature or pressure, such as, molecular weight, critical properties, and triple point properties.

Note

All CO_2Tab functions begin with the prefix CD.

Table 1: Overview of CO_2Tab Functions

Function	Calculates at Specified	Calling Sequence Example
Saturated Vapor, Liquid, and Two-Phase Functions		
CDPSAT	pressure *(P)*	CDPSAT(pressure, quality, code, *units*)
CDTSAT	temperature *(T)*	CDTSAT(temperature, quality, code, *units*)
Superheated or Subcooled Functions		
CDTP	temperature and pressure *(T-P)*	CDTP(temperature, pressure, code, *units*)
CDTV	temperature and volume *(T-V)*	CDTV(temperature, volume, code, *units*)
CDTH	temperature and enthalpy *(T-H)*	CDTH(temperature, enthalpy, code, *units*)
CDTS	temperature and entropy *(T-S)*	CDTS(temperature, entropy, code, *units*)
CDTU	temperature and internal energy *(T-U)*	CDTU(temperature, internal, code, *units*)
CDPV	pressure and volume *(P-V)*	CDPV(pressure, volume, code, *units*)
CDPH	pressure and enthalpy *(P-H)*	CDPH(pressure, enthalpy, code, *units*)
CDPS	pressure and entropy *(P-S)*	CDPS(pressure, entropy, code, *units*)
CDPU	pressure and internal energy *(P-U)*	CDPU(pressure, internal, code, *units*)
Melting and Sublimation Functions		
CDPMELT	pressure at specified temperature (T)	CDPMELT(temperature, *units*)
CDTMELT	temperature at specified pressure (P)	CDTMELT(pressure, *units*)
CDPSUBL	pressure at specified temperature (T)	CDPSUBL(temperature, *units*)
CDTSUBL	temperature at specified pressure (P)	CDTSUBL(pressure, *units*)
Solubility in Water Functions		
CDSOLU	temperature and total pressure	CDSOLU(temperature, pressure, code, *units*)
CDSOLUPP	temperature and CO2 partial pressure	CDSOLUPP(temperature, pressure, code, *units*)
Constant Properties Functions		
CDWM	Molecular weight	CDMW(*units*)
CDTC	Critical temperature	CDTC(*units*)
CDPC	Critical pressure	CDPC(*units*)
CDVC	Critical specific volume	CDVC(*units*)
CDRC	Critical specific density	CDRC(*units*)
CDZC	Critical compressibility factor	CDZC(*units*)
CDTPT	Triple point temperature	CDTPT(*units*)
CDTPP	Triple point pressure	CDTPP(*units*)
CDTMIN	Minimum temperature range	CDTMIN(*units*)
CDTMAX	Maximum temperature range	CDTMAX(*units*)
CDPMIN	Minimum pressure range	CDPMIN(*units*)
CDPMAX	Maximum pressure range	CDPMAX(*units*)

In the CO_2Tab functions, *units* is an optional argument. You need not specify *units*, in which case all requested properties are returned in Metric/SI units, that is, the default value is 0. For carbon dioxide properties in English units, set *units* to 1. However, in Lotus 1-2-3 *units* is a required argument, that it, it has to be explicitly specified as 0 for Metric/SI units and 1 for English units.

The argument quality is used to specify the saturated carbon dioxide quality (vapor mass fraction) or to specify the two-phase carbon dioxide quality. Use a value of 1 for saturated vapor, 0 for saturated liquid and between 0 and 1 for two-phase. The CO_2Tab functions also return quality as a calculated property. If the quality cannot be determined, then a value of -1 is returned. If the phase is superheated vapor, then a quality of -2 is returned, and if the phase is subcooled liquid a quality of -3 is returned.

The argument code, is an integer argument or a string identifier that specifies the type of carbon dioxide property requested. Valid values of code and the units in which they are returned are shown in the table below. For example, to obtain the enthalpy you can specify a code of either 8 or H.

Table 2: Property Codes for Thermodynamic and Transport Properties

	Code	Property	Metric Units	English Units
0	T	Temperature, T	°C	°F
1	P	Pressure, P	bar	psia
2	V	Volume, V	m3/kg	ft3/lb
3	D	Density, ρ	kg/m3	lb/ft3
4	Z	Compressibility factor, Z	dimensionless	dimensionless
5	A	Helmoltz free energy, A	kJ/kg	Btu/lb
6	S	Entropy, S	kJ/(kg·°C)	Btu/(lb·°F)
7	U	Internal energy, U	kJ/kg	Btu/lb
8	H	Enthalpy, H	kJ/kg	Btu/lb
9	G	Gibbs free energy, G	kJ/kg	Btu/lb
10	CV	Heat capacity at constant volume, C_v	kJ/(kg·°C)	Btu/(lb·°F)
11	CP	Heat capacity at constant pressure, C_p	kJ/(kg·°C)	Btu/(lb·°F)
12	W	Speed of sound, v	m/s	ft/s
13	ALPHA	Coefficient of thermal expansion, $\alpha = \rho(\partial V/\partial T)_P$	1/°C	1/°F
14	KAPPA	Isothermal compressibility, $\kappa = -\rho(\partial V/\partial P)_T$	1/bar	1/psia
15	DPDT	dpdt, $(\partial P/\partial T)_V$	bar/°C	psia/°F
16	DVDT	dvdt, $(\partial V/\partial T)_P$	m3/(kg·°C)	ft3/(lb·°F)
17	DVDP	dvdp, $(\partial V/\partial P)_T$	m3/(kg·bar)	ft3/(lb·psi)
18	MU	Viscosity (dynamic), μ	μPa·s	lb/(ft·hr)
19	KT	Thermal conductivity, K	W/(m·°C)	Btu/(hr·ft·°F)
20	ST	Surface tension, σ	N/m	N/m
21	PR	Prandtl number, N_{Pr}	dimensionless	dimensionless
22	DC	Static dielectric constant	dimensionless	dimensionless
23	IJT	Isothermal Joule-Thomson coefficient	kJ/(kg·bar)	Btu/(lb·psia)
24	JT	Joule-Thomson coefficient	°C/bar	°F/psia
25	Q	Quality (vapor mass fraction)	dimensionless	dimensionless

Note

By definition, the thermodynamic reference state of carbon dioxide is at a temperature of 25ºC (298.15K) and 0.101325 MPa where the ideal gas enthalpy and entropy are set to zero.

Functions for Saturated Properties

The functions for saturated carbon dioxide properties calculate vapor, liquid or two-phase properties at either specified pressure or specified temperature. The applicable range of these functions is from the triple point up to the critical point.

Depending on your choice of independent variable, the two functions you can choose are:

Independent Variable	Use Function
Pressure	CDPSAT
Temperature	CDTSAT

These functions are described in detail below.

CDPSAT

Calculates the saturated vapor or liquid property at the specified pressure

Syntax

CDPSAT(pressure, quality, property_code, *units*)

Arguments

pressure	is the pressure at which the saturated property is required. See the Remarks section for acceptable pressure units.
quality	is 1 for vapor phase properties, 0 for liquid phase properties and between 0 and 1 for two-phase.
property_code	is an integer property code or a string identifier that specifies the type of property required. See Table 2: Property Codes for Thermodynamic and Transport Properties (page 19) for a listing of valid property codes.
units	is an optional integer argument. For Metric/SI units, specify a value of 0 (or leave empty). For English units, specify a value of 1.

Remarks

- The specified pressure unit must be in bar if *units* is 0; and must be in psia if *units* is 1.
- The pressure must be greater than or equal to the Triple Point Pressure and less than or equal to the Critical Pressure.

- If any of the arguments are invalid or if the arguments are outside the acceptable bounds, the function returns the #VALUE! error.

CDTSAT

Calculates the saturated vapor, liquid or two-phase property at the specified temperature.

Syntax

CDTSAT(temperature, quality, property_code, *units*)

Arguments

temperature	is the temperature at which the saturated property is required. See the Remarks section for acceptable temperature units.
quality	is 1 for vapor phase properties, 0 for liquid phase properties and between 0 and 1 for two-phase.
property_code	is an integer property code or string identifier that specifies the type of property required. See Table 2: Property Codes for Thermodynamic and Transport Properties (page 19) for a listing of valid property codes and their meaning.
units	is an optional integer argument. For Metric/SI units, specify a value of 0 (or leave empty). For English units, specify a value of 1.

Remarks

- The specified temperature unit must be in °C if *units* is 0; and must be in °F if *units* is 1.
- The specified temperature must be greater than or equal to the Triple Point Temperature (0.01°C) and less than or equal to the Critical Temperature (373.976°C).
- If any of the arguments are invalid or if the arguments are outside the acceptable bounds, the function returns the #VALUE! error.

Functions for Superheated or Subcooled Properties

The functions in this category calculate the superheated vapor or subcooled liquid property at any two specified independent variables. These functions have a wide range of applicability. Generally, the properties returned by these functions are acceptable within the following ranges:

- Pressure (P, bar): $0 \le P \le 8{,}000$
- Temperature (T, °C): $-73.15 \le T \le 826.85$

The superheated/subcooled functions require two independent variables as input. Use the following table as a guide to select the appropriate function.

Specified Independent Variable		
First Variable	**Second Variable**	**Use Function**
Temperature, *T*	Pressure, *P*	CDTP
Temperature, *T*	Volume, *V*	CDTV
Temperature, *T*	Enthalpy, *H*	CDTH
Temperature, *T*	Entropy, *S*	CDTS
Temperature, *T*	Internal Energy, *U*	CDTU
Pressure, *P*	Volume, *V*	CDPV
Pressure, *P*	Enthalpy, *H*	CDPH
Pressure, *P*	Entropy, *S*	CDPS
Pressure, *P*	Internal Energy, *U*	CDPU

All of these functions have a similar syntax and arguments as described below.

General Description

General Syntax

CDXX(first_variable, second_variable, property_code, *units*)

Replace CDXX with the appropriate function name.

General Arguments

first_variable — is the first independent variable.

second_variable — is the second independent variable .

property_code — is an integer property code or a string identifier that specifies the type of property required. See Table 2: Property Codes for Thermodynamic and Transport Properties (page 19) for a listing of valid property codes and their meaning.

units — is an optional integer argument. For Metric/SI units, specify a value of 0 (or leave empty). For English units, specify a value

of 1.

General Remarks

- If any of the arguments are invalid or if the arguments are outside the acceptable bounds, the function returns the #VALUE! error.
- Some of these functions solve for the pressure iteratively. Therefore, it is possible that the function may fail to converge, in which case the function returns the above error codes.

Functions for Constant Properties

The functions in this category return constant properties, such as, the molecular weight, critical properties, and triple point properties.

The constant property functions are:

Function	Calculates	Metric/SI Units	English Units
CDMW	Molecular weight	kg/kmol	lb/lbmol
CDTC	Critical temperature	°C	°F
CDPC	Critical pressure	bar	psia
CDVC	Critical specific volume	m^3/kg	ft^3/lb
CDRC	Critical specific density	kg/m^3	lb/ft^3
CDZC	Critical compressibility factor	dimensionless	dimensionless
CDTPT	Triple point temperature	°C	°F
CDTPP	Triple point pressure	bar	psia
CDTMIN	Minimum temperature	°C	°F
CDTMAX	Maximum temperature	°C	°F
CDPMIN	Minimum pressure	bar	psia
CDPMAX	Maximum pressure	bar	psia

All of the functions in this category take an optional integer argument: *units* which is 0 or Metric units. For constant properties in English units set this argument to 1.

Note

If you want to use the default argument you need not specify any value. In this case, use the "empty" parenthesis, for example, `=CDTC()`.

Melting and Sublimation Line Functions

The functions in this category obtain the temperature or pressure along the melting and sublimation lines. The functions in this category are:

Function	Calculates
CDPMELT	Melting pressure at specified temperature
CDTMELT	Melting temperature at specified pressure
CDPSUBL	Sublimation pressure at specified temperature
CDTSUBL	Sublimation temperature at specified pressure

All of these functions have a similar syntax and arguments as described below.

General Description

General Syntax

CDXX(input, *units*)

Replace CDXX with the appropriate function name.

General Arguments

input	is the input variable (temperature or pressure)
units	is an optional integer argument. For Metric/SI units, specify a value of 0 (or leave empty). For English units, specify a value of 1.

General Remarks

- If any of the arguments are invalid or if the arguments are outside the acceptable bounds, the function returns the #VALUE! error.

Functions for Solubility in Water

The solubility functions return the solubility of carbon dioxide in water as a function of temperature and either total pressure or the partial pressure of carbon dioxide. The solubility functions are based on:

Reference

"The Solubility of Carbon Dioxide in Water at Low Pressure", John J. Carroll, John D. Slupsky, Alan E. Mather, J. Phy. Chem. Ref. Data, Vol. 20, No. 6, 1991

The functions are:

Function	Calculates
CDSOLU	Solubility at specified temperature and total pressure
CDSOLUPP	Solubility at specified temperature and CO_2 partial pressure

Each of these functions takes a property code as:

Table 3: Solubility Property Codes

Property Code		Description
0	XCO2	Liquid mole fraction of CO_2 (molar solubility)
1	YCO2	Vapor mole fraction of CO_2
2	XWCO2	Liquid mass fraction of CO_2 (mass solubility)
3	YWCO2	Vapor mass fraction of CO_2

Range

The solubility functions are valid from 0ºC to 160ºC up to a total pressures of 10 bar absolute.

CDSOLU

Calculates the solubility of carbon dioxide in water at the specified temperature and total pressure.

Syntax

CDSOLU(temperature, pressure, property_code, *units*)

Arguments

temperature	is the temperature at which the solubility is required.
pressure	is the total pressure at which the solubility is required.
property_code	is an integer property code or string identifier that specifies the type of solubility required. See Table 3: Solubility Property Codes (page 25) for a listing of valid property codes and their meaning.
units	is an optional integer argument. For Metric/SI units, specify a value of 0 (or leave empty). For English units, specify a value of 1.

CDSOLUPP

Calculates the solubility of carbon dioxide in water at the specified temperature and CO_2 partial pressure.

Syntax

CDSOLU(temperature, partial_pressure, property_code, *units*)

Arguments

temperature	is the temperature at which the solubility is required.
partial_pressure	is the CO_2 partial pressure at which the solubility is required.
property_code	is an integer property code or string identifier that specifies the type of solubility required. See Table 3: Solubility Property Codes (page 25) for a listing of valid property codes and their meaning.
units	is an optional integer argument. For Metric/SI units, specify a value of 0 (or leave empty). For English units, specify a value of 1.