Project OpSim – Specifications Document

Version 1.0.2

Preamble

The present document establishes specifications for Open Source Process Simulator (OpSim) project. The effort of development will be segmented in three major areas related to corresponding aspects of the simulator: the user interface, the engine and the data access.

This document is opened for insertions from our development community and will be included in the code repository HTML format, in order that concurrent modifications become feasible.

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1 What is new?

3/17/2006

1) Updated specs for database files (Samuel)

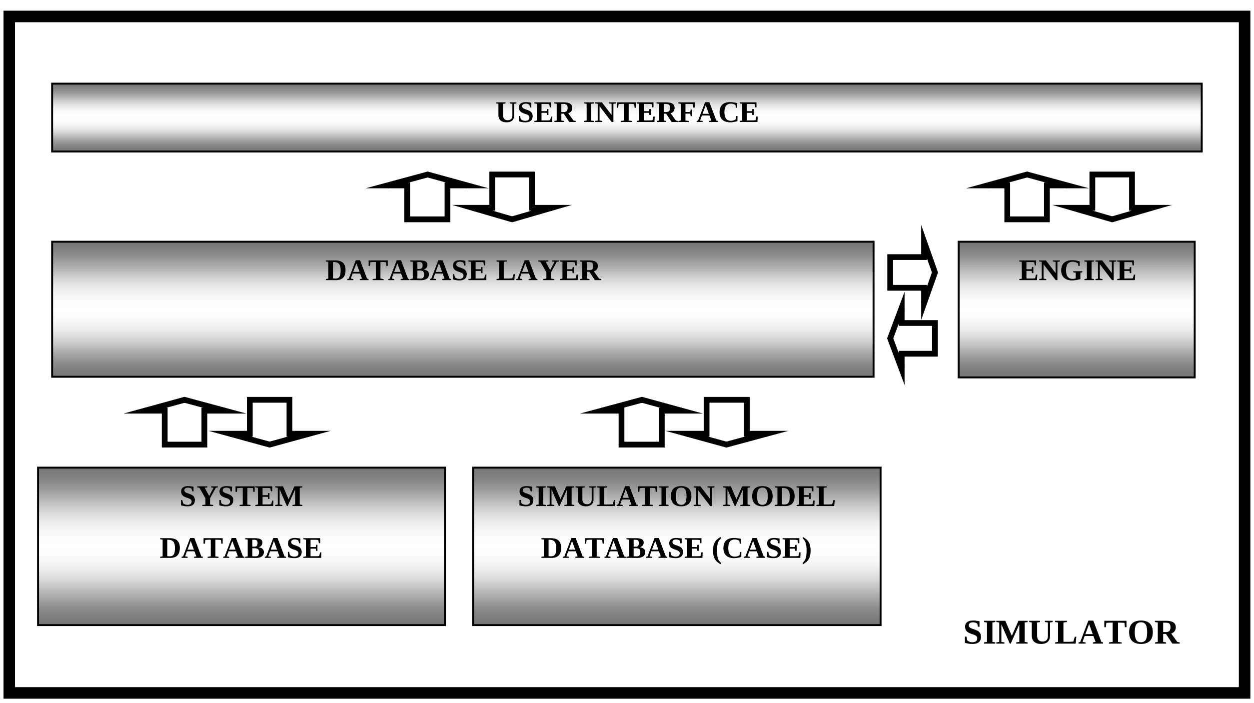
10/03/2006

1) Added schedule proposal (from Hazem).
2) Added specs (from Rahul Anantharaman).
3) Added structure proposal (from Hazem).

2 Overall Architecture

1) The whole simulator structure is divided in three major parts: user interface, engine and data accesses layer. Each one aspect has its own functionality and provides services to each other, through precisely defined boundaries. They exchange information only through these boundaries.

2) A diagram illustrating this is shown below:



3 Interface

3) The simulator will have an intuitive and friendly graphic user interface (GUI). No development effort is going to be spent in implementing a command line. Interaction with the simulation engine will be provided only through the GUI. An immediate consequence of this approach is that, at the first time, external applications will have no means to use the simulation engine (what would be possible with a command line user interface, using the standard I/O pipes). However there is a remedy to this shortcoming, which does not suffer with the poor performance of communication processes via the use of pipes (see section Engine).

4) Fundamental elements of the interface are:

5) <u>Component Pallet</u> for unit operations and other components.

6) <u>Workspace</u> to build the flow sheet. The Workspace has a drag-drop style, so that elements of the simulation model can be point-clicked and dragged from the Component Pallet

7) <u>Report Forms</u> output module.

8) Components of a simulation case are defined in the graphical environment through forms. A list of input forms is shown below:

COMPONENT	DESCRIPTION
Stream	Process stream between two unit ops equipment.
Two Phase Separator	
Three Phase Separator	
Compressor	
Valve	
Pipe	
Heat exchanger	
Distillation Column	
Pump	
Tank	
Heater	
Cooler	
?	
?	
?	

4 Engine

1) Simulation engine will be steady state. Future version may leverage the models to be transient.

2) Simulation engine is closely linked to the user interface, though completely impendent of it. This goal may be achieved through an interfacing layer between both.

3) With this partition, in a later stage of development, the engine may be packaged in a library (dynamic link library or shared object on Linux) and its interfaces exposed to the system environment. This design permits other applications to direct link and use the simulation engine, completely new user interfaces may be design even using another programming languages.

4) The engine comprises basically:

   4.1) Solver.

   4.2) Mathematical models for each unit operation or simulation component.

   4.3) Thermodynamic models.

5) Accessing the database is not a functionality of the engine. It does nothing about the database structure. The data needed to solve the simulation are supplied to the engine by other parts of the simulator. After solving the simulation case, the engine supplies the rest of the simulator (interface and database layer) with the partial or final results.

5 Data Access

1) The simulator will have input/output (I/O) capabilities to save and reload a simulation case from a file.

2) All the data comprising one simulation case is stored in only one file.

3) The file I/O operation will be performed through the embedded Relational Database Management System (DBMS): Firebird.

4) The technical reasoning to use a DBMS is:

   4.1) Low level storage operations are isolated from the simulator.

4.2) We do not need to worry about a file format. This is left to the DBMS. If the file format of the DBMS changes, we only need to dump the data and inject in the new version. A custom file format would require exhaustive implementation of converting routines.

4.3) Reliable data storage. DBMS uses sophisticated schemes to access the hard disk in order to protect data.

4.4) Fragmented access to the data file. A custom data file commonly imposes a three stage cycle: reading the file at once, and storing it in the RAM; modifying the data in RAM and writing the whole file at once. DBMS allows read/write small pieces of information in a much more efficient manner.

4.5) Concurrent access to the data in the simulation file. DBMS permits multiple applications accessing the very same simulation case, what is not allowed with a custom formatted file. A simulation case could be built simultaneously by many individuals remotely apart, via the internet, for example, or a local/wide area network (LAN/WAN).

5) The technical reasoning to use a Firebird is:

5.1) Firebird is an industrial strength DBMS with decades of corporate use.

5.2) Firebird is open source, free of charge, with a very proud active community. The licensing agreement even allows its use with commercial applications, without restrictions (LGPL like).

5.3) Can be easily embedded into the simulator.

5.4) Can be easily scaled up to client/server, allowing simultaneous access of multiple users.

5.5) Available in several operating systems.

5.6) Have a very small footprint and the most advantageous relation [feature set]/[footprint].

5.7) Very fine integration support with Lazarus. Some Delphi components are directly compatible with Lazarus, but regarding the best one (IBObjects), I am not so sure. Anyway, there are native components for a data access in Lazarus.

5.1 Database Structure

1) The data utilized by the simulator is stored in two databases:

1.1) System Database: SYSDATA.ODB, used to store intrinsic to the whole system of the simulator, e.g. preferences, environment conjurations, etc. The extension “ODB” stands for “Opsim DataBase”

1.2) Model Database: [model-name].OSC, that store the whole data of the simulation model (case) currently opened at the simulator environment. The extension “OSC” stands for “Opsim Simulation Case”

5.1.1. The System Database

The system database is comprised by the following tables:

1) Units of measures used in conversions.

2) Sets of units.

3) What more???????

1. UNITS OF MEASUREMENT: holds data regarding the units of measurement used in the simulator. This table will be used to build custom sets of units.

PHISICAL TABLE NAME: UNIT_MEASURE			
FIELD NAME	**FIELD DESCRIPTION**	**FIELD TYPE**	**FIELD SIZE (BYTES)**
ID	Internal identification used in referential integrity of the data.	INTEGER (AUTO INCREMENT)	
NAME	Name of the unit.	TEXT	70
SYMBOL	Symbol of the unit in normalized text (e.g. W/m2K or W/m^2.K)	TEXT	30
CONV_FACTOR_INTERSECT_SI	Intersect conversion factor to the metric system of measurement.	TEXT	100
CONV_FACTOR_SLOPE_SI	Slope conversion factor to the metric system of	TEXT	100

	measurement.		
SOMETHING MORE??????????			

2. UNIT SETS OF MEASUREMENT: hold unit sets of measurement. A set of units should be used while building the simulation model. Each unit of measurement contained in the set, gets an entry on this table.

PHISICAL TABLE NAME: UNIT_MEASURE_SET			
FIELD NAME	**FIELD DESCRIPTION**	**FIELD TYPE**	**FIELD SIZE (BYTES)**
ID	Internal identification used in referential integrity of the data.	INTEGER (AUTO INCREMENT)	
NAME	Name of the unit set (e.g. SI, EuroSI, English System, etc.)	TEXT	50
UNIT_MEASURE_ID	ID of the unit of measurement.	INTEGER	
SOMETHING MORE??????????			

3. PROPERTIES OF PURE SUBSTANCES: holds data regarding the properties of the pure substances.

PHISICAL TABLE NAME: PROP_PURE_SUBST			
FIELD NAME	**FIELD DESCRIPTION**	**FIELD TYPE**	**FIELD SIZE (BYTES)**
ID	Internal identification used in referential integrity of the data.	INTEGER (AUTO INCREMENT)	
CODE	This is a custom code that may be show to the user. It is not used to create relationship between tables of the database.	INTEGER	

NAME	Name of the substance.	TEXT	70
NAME_IUPAC	IUPAC name o the substance.	TEXT	100
CHEMICAL_FORMULA	The chemical formula of the substance (e.g. CH4)	TEXT	100
MOLECULAR_WEIGHT	The molecular weight.	REAL	
TC	Critical Temperature (K)	REAL	
PC	Critical Pressure (Pa)	REAL	
VC	Critical Volume (m3/kmol)	REAL	
API	API gravity	REAL	
ACC	Accentic Factor	REAL	
NBP	Normal Boiling Point (K)	REAL	
VNB	Viscosity at NBP (kgf.hr/m2)	REAL	
HF	Ideal Gas Heat of Formation at Standard temperature (J/kg)	REAL	
GF	Ideal Gas Free Energy of Formation at Standard Temperature (J/kg)	REAL	
IG_COEFF_1	Coefficient 1 to calculate Ideal Gas Thermodynamic properties (J/kg)	REAL	
IG_COEFF_2	Coefficient 2 to calculate Ideal Gas Thermodynamic properties (J/kg/K)	REAL	
IG_COEFF_3	Coefficient 3 to calculate Ideal Gas Thermodynamic properties (J/kg/K2)	REAL	
IG_COEFF_4	Coefficient 4 to calculate Ideal Gas Thermodynamic properties (J/kg/K3)	REAL	
IG_COEFF_5	Coefficient 5 to calculate	REAL	

	Ideal Gas Thermodynamic properties (J/kg/K4)		
IG_COEFF_6	Coefficient 6 to calculate Ideal Gas Thermodynamic properties (J/kg/K5)	REAL	
IG_COEFF_7	Coefficient 7 to calculate Ideal Gas Thermodynamic properties (J/kg/K6)	REAL	
SOMETHING MORE??????????			

5.1.2. The Model Database

The model database contains:

1) Global options of the simulation model.

2) One different table for each type of component added to the model, being it a unit operation, a stream, or whatever.

3) Other tables??????

4. PUMPS ON THE SIMULATION MODEL: holds data regarding all the pumps components used in the simulation model. Each pump placed by the user on the PFD diagram, generates a record on this table. Since we may need other tables to keep other others unit operation or components, let establish a prefix now on "PFD_" used to name each table containing unit operation/component of a simulation case.

PHISICAL TABLE NAME: PFD_PUMP			
FIELD NAME	**FIELD DESCRIPTION**	**FIELD TYPE**	**FIELD SIZE (BYTES)**
ID	Internal identification used in referential integrity of the data.	INTEGER (AUTO INCREMENT)	
CODE	This is a custom code that may be shown to	INTEGER	

	the user. It is not used to create relationship between tables of the database.		
NAME	Descriptive name of the pump.	TEXT	70
LABEL	Label used to identification on the PFD.	TEXT	50
HEAD	The head supported by the pump with zero flow rate	REAL	
HEAD_UNIT_ID	ID of the unit of measurement used to specify the HEAD field. Needed to do conversions.	INTEGER	

6 CAPE-OPEN STANDARDS

6.1.1. Standardized Models or Equations (CAPE-OPEN)

This Appendix contains a selection of model equations which may be part of a PPDB. This selection is not meant to be exclusive, every PPDB can add its own equations.

Predictive equations like UNIFAC are exclude on purpose, because they do not need any model parameters.

short name of method	full name of method	equation	parameters
Antoine	Antoine vapor pressure equation	$\log(p) = a - b/(T+c)$	a, b, c
Wrede	Wrede vapor pressure equation	$\log(p) = a - b/T$	a, b
Wrede-ln	Wrede vapor pressure equation	$\ln(p) = a - b/T$	a, b
Cragoe	Cragoe vapor pressure equation	$\log(p) = a + b/T + c*T + d*T^2$	a, b, c, d
Riedel	Riedel vapor pressure equation	$\ln(p) = a - b/T + c*T + d*T^2 + e*\ln(T)$	a, b, c, d, e

short name of method	full name of method	equation	parameters
Wagner	Wagner vapor pressure equation	$\ln(p/p_{crit}) = (a*x + b*x^{(3/2)} + c*x^3 + d*x^6)/(T/T_{crit}); x = 1 - T/T_{crit}$	a, b, c, d, criticalPressure, criticalTemperature
Wagner2	2nd Wagner vapor pressure equation	$\ln(p/p_{crit}) = (a*x + b*x^{(3/2)} + c*x^3 + d*x^7 + e*x^9)/(T/T_{crit}); x = 1 - T/T_{crit}$	a, b, c, d, e, criticalPressure, criticalTemperature
Wagner3	Wagner vapor pressure equation (Aspen)	$\ln(p/p_{crit}) = (a*x + b*x^{(3/2)} + c*x^3 + d*x^4)/(T/T_{crit}); x = 1 - T/T_{crit}$	a, b, c, d, criticalPressure, criticalTemperature
Chebyshev	Chebyshev vapor pressure equation	$T*\log(p) = c_0/2 + \sum_{(s)}[c_s * E_s(x)]$; $x = 2*T - (T_{max}+T_{min})/(T_{max}-T_{min})$; $E_s(x)$ = Chebyshev polynomial of order s	c_0, c_1, c_2, ..., T_min, T_max
polynomial	polynomial	$y = a + b*x + c*x^2 + ...+ j*x^9$ x = any property	a, b, c, d, e, f, g, h, i, j
vapor pressure_1	vapor pressure equation	$\ln(p) = a + b*T + c/T + d/T^2$	a, b, c, d
mod.Antoine(Hysys)	modified Antoine vapor pressure equation (Hysys[9], page A-36)	$\ln(p) = A + B/(T+C) + D*T + E*\ln(T) + F*T^G$	A, B, C, D, E, F, G
mod.Antoine(Aspen)	modified Antoine vapor pressure equation (Aspen[7], page 3-80)	$\ln(p) = A + B/(T+C) + D*\ln(T) + E*T^F$	A, B, C, D, E, F
Jones-Dole	Jones-Dole equation	$\eta/\eta_0 = 1 + a*\sqrt{c} + b*c$	a, b, viscosity_0
Yen-Woods	Yen-Woods equation for densities	$d = d_{crit} * (a + \sum_{(j)}(k_j)*(1-T/T_{crit})^{(j/3)})$	criticalDensity, criticalTemperature, a, k_0, k_1, k_2, ...
Antoine viscosity	Antoine equation for the viscosity	$\ln(\eta) = a + b/(T+c)$	a, b, c
Riedel therm.cond.	Riedel equation for thermal conductivities	$\kappa = a * (1 + (20/3)*(1 - T/T_{crit})^{(2/3)})$	a, criticalTemperature
Sprow/Prausnitz	Surface Tension after Sprow and Prausnitz	$\sigma = a * (1 - T/T_{crit})^b$	a, b, criticalTemperature
modified polynomial	modified polynomial	$property = a + b/T + c/T^2 + d*T + e*T^2 + f*T^3 + ...$	a, b, c, d, e, f, ...
Yuan/Mok	Yuan - Mok equation for the heat capacity	$c_p = a + b * \exp(-c/T^n)$	a, b, c, n
Redlich-Kister	Redlich-Kister equation for excess properties in binary systems	Δ property $= x_1 * x_2 * \Sigma_{(i)}(a_i*(x_1-x_2)^i)$	a_0, a_1, a_2, a_3, ...
thermal conductivity (NEL)	NEL equation for thermal conductivity	$\kappa = a*(1 + b*x^{(1/3)} + c*x^{(2/3)} + d*x); x=1-T/T_{crit}$	a, b, c, d, criticalTemperature
virial equation	virial equation	$Z = 1 + vc_2*p + vc_3*p^2 + vc_4*p^4 + ...$	vc_2, vc_3, vc_4

BWR	BWR-equation of state	$p = R*T*d + (b_0*R*T - a_0 - c_0/T_2)*d_2 + (b_0*R*T - a_0)*d_3 + a*\alpha*d_6 + (c*d_3/T_2)*(1 + \gamma*d_2)*\exp(-\gamma*d_2)$	a_0, b_0, c_0, a, b, c, alpha, gamma
BWR-Lee-Starling	Benedict-Webb-Rubin-Lee-Starling equation of state (Aspen[7], page 3-8)	$Z_m = Z_{m0} + \gamma_i*Z_{m1}$; Z_{m0}, Z_{m1} =function($T, T_{crit}, v_m, v_{crit,m}$)	criticalTemperature _i, criticalVolume_i, gamma_i, epsilon_i_j, eta_i_j
Hayden-O'Connel	Hayden-O'Connel equation of state (Aspen[7], page 3-9)	$Z_m = 1 + B*p/R*T$; $B = \Sigma_{(i)}\Sigma_{(j)}B_{ij}(T)$	B_i_j
Lee-Kesler	Lee-Kesler equation of state (Aspen[7], page 3-18)	$Z = Z_0 + (Z_r - Z_0)*\omega/\omega_r$ $Z_0 = fct_0(T/T_{crit}, p/p_{rit})$ $Z_r = fct_r(T/T_{crit}, p/p_{crit})$	criticalTemperature, criticalPressure, omega
Lee-Kesler-Plöcker	Lee-Kesler-Plöcker equation of state (Aspen[7], page 3-19)	$Z_m = Z_{m0} + (\omega/\omega_r)*(Z_{m0} - Z_{mr})$; $Z_{m0} = fct_0(T, T_{crit}, v_m, v_{crit,m})$; $Z_{mr} = fct_f(T, T_{crit}, v_m, v_{crit,m})$ mixing rules for $v_{crit,m}$, T_{crit}	criticalTemperature, criticalPressure, vcriticalVolume, omega, Z_c_i, K_i_j
Peng-Robinson-Boston-Mathias	Peng-Robinson-Boston-Mathias equation of state (Aspen[7], page 325)	$p = R*T/(v_m-b) - a/[v_m*(v_m+b)+b*(v_m-b)]$	criticalTemperature_i, criticalPressure_i, omega_i, k_1_2
Redlich-Kwong	Redlich-Kwong equation of state (Aspen[7], page 3-27)	$p = R*T/(v_m-b) - (a/\sqrt{(T)})/[v_m*(v_m+b)]$	criticalTemperature_i, criticalPressure_i

short name of method	full name of method	equation	parameters
Redlich-Kwong-Aspen	Aspen modification of the Redlich-Kwong equation of state(Aspen[7], page 3-28)	$p = R*T/(v_m-b) - a/[v_m*(v_m+b)]$ with mixing rules	criticalTemperature_i, criticalPressure_i, omega_i, eta_i,k_0_a__i_j, k_1_a_i_j, k_0_D_i_j, k_1_D_i_j,
Redlich-Kwong-Soave-Boston-Mathias	Redlich-Kwong equation of state with Boston-Mathias alpha function (Aspen[7], page 3-29)	$p = R*T/(v_m-b) - a/[v_m*(v_m+b)]$ with mixing rules	criticalTemperature_i, criticalPressure_i, omega_i, k_i_j
Schwartzentruber-Renon	Schwartzentruber-Renon equation of state (Aspen[7], page 3-31)	$p = R*T/(V_m+c-b) - a/[(v_m+c)*(V_m+c+b)]$ with mixing rules	criticalTemperature_i, criticalPressure_i, omega_i, q_0_i, q_1_i, q_2_i, c_0_i, c_1_i, c_2_i, k_0_a_i-j, k_1_a_i_j, k_2_a_i_j, l_0_i_j, l_1_i_j, l_2_i_j, k_0_D_i_j, k_1_D_i_j, k_2_D_i_j
Peng-Robinson	standard Peng-Robinson equation of state (Aspen[7], page 3-34)	$p = R*T/(v_m-b) - a/[v_m*(v_m+b)+b*(v_m-b)]$	criticalTemperature_i, criticalPressure_i, omega_i (i=1..2), k_1_2
Redlich-Kwong-Soave	standard Redlich-Kwong-Soave equation of state (Aspen[7], page 335)	$p = R*T/(v_m-b) - a/[v_m*(v_m+b)]$ with mixing rules	criticalTemperature_i, criticalPressure_i, omega_i, k_i_j

Bromley-Pitzer	Bromley-Pitzer activity coefficient model (Aspen[7], page 3-54)		beta_ion, delta_ion, beta_0, beta_1, beta_2, beta_3
Chien-Null	Chien-Null model for calculation activity coefficient of highly non-ideal systems (Aspen[7], page 3-55)		a_i_j, b_i_j, v_i_j
Electrolyte-NRTL	NRTL activity coefficient model for electrolytes(Aspen[7], page 3-58)		A_B, B_B, C_B, r_i, A_BB, A_BsB, B_BBs, B_BsB, alpha_BB, F_BBs, F_BsB, G_BBs, G_BsB, C_ca_B, C_B_ca, D_ca_B, D_B_ca, E_ca_B, E_B-ca, alpha_ca_B, C_cas_cass, C_cass-cas, c_csa,cssa, C_cssa_csa, D_cas_cass,D_cass_cas, D_csa_cssa, D_cssa_csa, E_cas_cass, E_cass_cas,E_csa_cssa, E_cssa_csa, alpha_cas_cass, alpha_csa_cssa
NRTL	NRTL activity coefficient model (DDB[8], page XVI)		A_i_j, A_j_i, alpha (i,j=1...2)
extended NRTL (Aspen)	NRTL activity coefficient model (Aspen[7], page 3-62)		a_i_j, b_i_j, c_i_j, d_i_j, e_i_j, f_i_j (i,j=1...2)
general NRTL	general NRTL activity coefficient model (Hysys[9], page A-22)		form-of_equation, A_j_j, B_i_j, C_i_j, F_i_j, G_i_j, alpha1_i_j, alpha2_i_j (i,j=1...2)
Pitzer activity	Pitzer model for activity		beta_0, beta_1, beta_2,

short name of method	full name of method	equation	parameters
coefficient model	coefficients of aqueous systems (Aspen [7], page 3-63)		beta_3, C_p, theta_c_cs, theta_a_as, psi_c_cs_a, psi_c_a_as
Redlich-Kister	Redlich-Kister model for calculating activity coefficients (Aspen[7], page 3-66)		a_i_j, b_i_j, c_i_j, d_i_j, e_i_j, f_i_j, g_i_j, h_i_j, m_i_j, n_i_j, v_i
Scatchard-Hildebrand	Scatchard-Hildebrand model (Aspen[7], page 3-67)		criticalTemperature-i, delta_i, V_i_CVT, V_i_l
Margules	Margules equation for calculating liquid activity coefficients (DDB[8], page XVI)	$\ln(\gamma_i) = [A_{ij} + 2*(A_{ji}-A_{ij})*x_i](1-x_i)^2$	A_i_j
extended Margules	Margules equation for calculating liquid activity coefficients with temperature-independent parameters (Hysys[9], page A-24)	$\ln(\gamma_i) = (1-x_i)*+2*[A_i + 2+x_i*(B_i-A_i)]$; $A_i = \Sigma_{(j)}[x_j*(a_{ij}+b_{ij}*T)/(1-x_i)]$; $B_i = \Sigma_{(j)}[x_j*(a_{ji}+b_{ji}*T)/(1-x_i)]$	a_i_j, b_i_j (i,j=1...2)

three-suffix Margules	extended Margules equation for calculating liquid activity coefficients (Aspen[7], page 3-68)		a_i_j, b_i_j, c_i_j, d_i_j (i,j=1...2)
van Laar	van Laar equation for calculating liquid activity coefficients (DDB[8], page XVI)		A_i_j (i,j=1...2)
extended van Laar (Aspen)	extended van Laar equation for calculating liquid activity coefficients with temperature-independent parameters (Aspen[7], page 3-75)		a_i_j, b_i_j, c_i_j, d_i_j (i,j=1...2)
extended van Laar (Hysys)	extended van Laar equation for calculating liquid activity coefficients with temperature-independent parameters (Hysys[9], page A-28)		a_i_j, b_i_j (i,j=1...2)
Wilson	Wilson equation for calculating liquid activity coefficients (DDB[8], page XVI)		A_i_j (i,j=1...2)
extended Wilson (Aspen)	extended Wilson equation for calculating liquid activity (Aspen[7], page 3-78)		a_i_j, b_i_j, c_i_j, d_i_j (i,j=1...2)
extended Wilson (Hysys)	extended Wilson equation for calculating liquid activity coefficients with temperature-independent parameters (Hysys[9], page A-29)		a_i_j, b_i_j (i,j=1...2)
UNIQUAC	UNIQUAC equation for calculating liquid activity coefficients (DDB[8], page XVII)		u_i_j (i,j=1...2)
extended UNIQUAC (Aspen)	extended UNIQUAC equation for calculating liquid activity coefficients with temperature-independent parameters (Aspen[7], page 3-74)		a_i_j, b_i_j, c_i_j, d_i_j (i,j=1...2)

short name of method	full name of method	equation	parameters
extended UNIQUAC (Hysys)	extended UNIQUAC equation for calculating liquid activity coefficients with temperature-independent parameters (Hysys[9], page A-26)		a_i_j, b_i_j (i,j=1...2)
DIPPR107	DIPPR equation for the ideal heat capacity	$property = A + B[C/T/\sinh(C/T)]^2 + D[E/T/\cosh(E/T)]^2$	A, B, C, D, E
heat capacity (ASPEN)	Aspen[7]-equation for the solid heat capacity (page 3-102)	$C_p = c_1 + c_2*T + c_3*T^2 + c_4/T + c_5/T^2 + c_6/\sqrt{(T)}$	c1, c2, c3, c4, c5, c6
Barin	Barin equations for thermophysical property data	$G = a + b*T + c*(T*\ln(T)) + d*T^2 + e*T^3 + f*T^4 + g/T + h/T^2$	a, b, c, d, e,f, g, h
Andrade	Andrade equation for calculating the liquid viscosity	$\ln(\eta) = A + B/T + C*\ln(T)$	A, B, C

liquid viscosity (DIPPR)	DIPPR equation for the liquid viscosity	$\ln(\eta) = c_1 + c_2/T + c_3*\ln(T) + c_4*T^{c_5}$	c1, c2, c3, c4, c5
viscosity mixing rule	ASPEN[7] mixing rule for the liquid viscosity (listed under the heading Andrade/DIPPR, page 3-122)	$\ln(\eta) = \Sigma_{(i)}[x\_i*\ln(\eta_i)] + \Sigma_{(i,j)}[(a_{ij} + b_{ij}/T)*x_i*x_j + (c_{ij}+d_{ij}/T)*x_i^2*x_j^2]$	a_i_j, b_i_j, c_i_j, d_i_j
DIPPR102	DIPPR equation for the gas viscosity at 0 atm pressure and the gas thermal conductivity	$\text{property} = A*T^B/(1 + C/T + D/T^2)$	A, B, C, D
Chung-Lee-Starling	Chung-Lee-Starling correlation of the viscosity and thermal conductivity of liquid or gaseous mixtures (Aspen[7], page 3-127, 3138))		criticalTemperature_i, V_crit_i, dipole_moment_i, omega_i, kappa_i, xi_i_j, zeta_i_j
suface tension (DIPPR)	DIPPR correlation for surface tension	$\sigma = c1*(1-T_r)$^$(c_2 + c_3*T_r + c_4*T_r^2 + c_5*T_r^3)$; $T_r = T/T_{crit}$	c1, c2, c3, c4, c5, criticalTemperature
Hakim-Steinberg-Stiel	Hakim-Steinberg-Stiel equation for the surface tension (Aspen[7], page 3-155)		chi
DIPPR105		$\text{property} = A/B$^$[1+(1-T/C)^D]$	A, B, C, D
DIPPR101		$\text{property} = \exp(A + B/T + C*\ln(T) + D*T^E)$	A, B, C, D, E
DIPPR106		$\text{property} = A*(1-T_r)$^$(B + C*T_r + D*T_r^2)$; $T_r = T/T_{crrit}$	A,B,C,D, criticalTemperature
DIPPR104		$\text{property} = A + B/T + C/T^3 + D/T^8 + E/T^9$	A, B, C, D, E

Glossary of the symbols used in the column "equation"

cp heat capacity d density

d_{crit} critical density p

pressure p_{crit} critical pressure

R gas constant T

temperature T_{crit} critical

temperature v_m volume of a

mixture x_1 mole fraction of

compound 1 Z

compressibility factor Z_m

compressibility factor of a

mixture γ_i activity

coefficient of compound i

κthermal conductivity

ηviscosity η_0 viscosity at

zero concentration σsurface

tension

6.1.2. Standardized Units (CAPE-OPEN)

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
		no dimension	1.
rad			0.15915475
(BTU.ft3)^(1/2)	(J.m3)^(1/2)		5.4658892
(kJ.m3)^(1/2)	(J.m3)^(1/2)		31.6227766
(J/cm3)^(1/2)	(J/c3)^(1/2)		31.6227766
(BTU/ft3)^(1/2)	(J/m3)^(1/2)		1.9302605E2
(cal/cm3)^(1/2)	(J/m3)^(1/2)		2046.1671
(J/m3)^(1/2)	(J/m3)^(1/2)		1.
(kcal/m3)^(1/2)	(J/m3)^(1/2)		64.70548
(g.l)^(1/2)/min	(kg.m3)^(1/2)/s		1.6666667E-5
(kg.m3)^(1/2)/s	(kg.m3)^(1/2)/s		1.
(lb.ft3)^(1/2)/hr	(kg.m3)^(1/2)/s		3.1481311E-5
(lb.gal)^(1/2)/min	(kg.m3)^(1/2)/s		6.9061846E-4
bar.m6/mol2	Pa.m6/mol2		1.E5
bar.m9.K2/mol3	Pa.m9.K2/mol3		1.E5
bar.m9/mol3	Pa.m9/mol3		1.E5
A	A	Ampere	1.
mA	A		1.E-3
A/cm2	A/m2		10000.
A/m2	A/m2		1.
mA/cm2	A/m2		10.

mA/m2	A/m2		0.001
amagat	amagat		1.
atomic %	atomic fraction		0.01
atomic fraction	atomic fraction		1.
Debye	Coul.m		3.33564E-30
Coul	Coul		1.
Coul.m	Coul.m		1.
Coul/mol	Coul/mol		1.
Farad	Farad		1.
mFarad	Farad		0.001
nFarad	Farad		1.E-9
pFarad	Farad		1.E-12
Farad/m	Farad/m		1.
oz	g		28.349523
H	H		1.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
H/m	H/m		1.
hr-1	Hz		2.7777778E-4
Hz	Hz		1.
min-1	Hz		1.6666667E-2
s-1	Hz		1.
BTU	J	Britsh thermal unit	1055.0559
cal	J		4.1868
erg	J		1.E-7
eV	J		1.6021892E-19
GJ	J		1.00E9
J	J		1.
kcal	J		4.1868E3
kJ	J		1.E3
kp.m	J		9.80665
kW.hr	J		3.6E6
mJ	J		0.001
MMBTU	J	million BTUs	1.0550559E9
MMkcal	J	million kilocalories	4.1868E9
erg.mK/cm3	J.K/m3		0.1
J.K/m3	J.K/m3		1.
kJ/kg.degC	J.kg.K		1.0E3

J.s	J.s		1.
J/Hz	J.s		1.
J.s/mol	J.s/mol		1.
BTU/cycle	J/cycle		1054.35
cal/cycle	J/cycle		4.1868
GJ/cycle	J/cycle		1.0E9
J/cycle	J/cycle		1.
kcal/cycle	J/cycle		1000.
MMBTU/cycle	J/cycle		1.0550559E9
MMkcal/cycle	J/cycle		4.1868E9
J/kg.degC	J/g.K		1.E-3
J/kg.K	J/g.K		1.E-3
kcal/g.degC	J/g.K		4.1868E3
BTU/degF	J/K	British thermal unit per degrees Fahrenheit	1.899101E3
cal/K	J/K		4.1868
J/K	J/K		1.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
kcal/K	J/K		4.1868E3
kJ/K	J/K		1.E3
kcal/degC.hr	J/K.s		1.163
BTU/lb	J/kg	British thermal unit per pound avdp.	2.32600E3
cal/g	J/kg		4.1868E3
cal/g	J/kg		4186.8
cal/kg	J/kg		4.1868
J/g	J/kg		1.E3
J/kg	J/kg		1.
kcal(th)/kg	J/kg		4184.
kcal/g	J/kg		4186.8E3
kcal/kg	J/kg		4186.8
kJ/g	J/kg		1.E6
kJ/g	J/kg		1.E6
kJ/kg	J/kg		1.0E3
kW.hr/ton	J/kg		3600.
mJ/kg	J/kg		0.001
MJ/kg	J/kg		1.E6

MMBTU/lb	J/kg	million BTU per pound (avdp)	2.32444E9
MMkcal/kg	J/kg		4.1868E9
BTU/lb.degF	J/kg.K		4.1868E3
BTU/lb.Rnk	J/kg.K		4.1868E3
cal(th)/g.K	J/kg.K		4148.
cal/g.degC	J/kg.K		4.1868E3
cal/g.K	J/kg.K		4186.8
cal/kg.degC	J/kg.K		4.1868
cal/kg.K	J/kg.K		4.1868
J/g.degC	J/kg.K		1.E3
J/g.K	J/kg.K		1.E3
J/kg.K	J/kg.K		1.
kcal/g.K	J/kg.K		4186.8E3
kcal/kg.degC	J/kg.K		4186.8
kcal/kg.K	J/kg.K		4.1868E3
kcal/kg.K	J/kg.K		4186.8
kJ/g.degC	J/kg.K		1.E6
kJ/g.K	J/kg.K		1.E6
kJ/kg.K	J/kg.K		1000.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
BTU/lb.Rnk2	J/kg.K2		7536.2403
J/kg.K2	J/kg.K2		1.
kcal/kg.K2	J/kg.K2		4186.8
kJ/g.K2	J/kg.K2		1.E6
kJ/kg.K2	J/kg.K2		1000.
BTU/lb.Rnk3	J/kg.K3		13565.2326
kcal/kg.K3	J/kg.K3		4186.8
kJ/g.K3	J/kg.K3		1.E6
kJ/kg.K3	J/kg.K3		1000.
BTU/lb.Rnk4	J/kg.K4		24417.4187
kcal/kg.K4	J/kg.K4		4186.8
kJ/g.K4	J/kg.K4		1.E6
kJ/kg.K4	J/kg.K4		1000.
BTU/lb.Rnk5	J/kg.K5		43951.3537
kcal/kg.K5	J/kg.K5		4186.8
kJ/g.K5	J/kg.K5		1.E6
kJ/kg.K5	J/kg.K5		1000.

J/g.bar	J/kg.Pa		0.01
J/kg.Pa	J/kg.Pa		1.
J/g.bar.K	J/kg.Pa.K		0.01
J/kg.Pa.K	J/kg.Pa.K		1.
J/g.bar2.K	J/kg.Pa2.K		1.E-7
J/kg.Pa2.K	J/kg.Pa2.K		1.
BTU/ft.hr	J/m.s		0.96150757
cal/m.s	J/m.s		4.1868
J/m.s	J/m.s		1.
MMBTU/hr.ft	J/m.s		0.96150757E6
BTU.ft/ft2.hr.Rnk	J/m.s.K		0.09495505
BTU/ft.hr.degF	J/m.s.K		1.730734744
cal.cm/s.cm2.K	J/m.s.K		418.68
kcal/m.hr.degC	J/m.s.K		1.163
MMBTU/hr.ft2.Rnk	J/m.s.K		5.6782633E6
cal/cm2	J/m2		4.1868E4
erg/cm2	J/m2		1.E-3
J/cm2	J/m2		1.E4
J/m2	J/m2		1.
kcal/m2	J/m2		4.1868E3

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
kJ/m2	J/m2		1.E3
BTU/ft2.hr.Rnk	J/m2.K		5.6782636
cal/cm2.K	J/m2.K		4.1868E4
cal/m2.K	J/m2.K		4.1868
J/cm2.K	J/m2.K		1.E4
J/m2.K	J/m2.K		1.
kcal/m2.K	J/m2.K		4.1868E3
kJ/m2.K	J/m2.K		1.E3
BTU/ft2.hr	J/m2.s		3.1545909
BTU/ft2.hr.degF	J/m2.s.K		5.6782636
J/m2.s.K	J/m2.s.K		1.0
BTU/ft3	J/m3		29.875856
cal/cm3	J/m3		4.1868E6
J/m3	J/m3		1.
kcal/m3	J/m3		4.1868E3
kJ/cm3	J/m3		1000.

kJ/m3	J/m3		1.0E3
BTU/ft3.Rnk	J/m3.K		53.776541
cal/cm3.K	J/m3.K		4.1868E6
J/cm3.K	J/m3.K		1000000.
J/m3.K	J/m3.K		1.
kcal/m3.K	J/m3.K		4.1868E3
kJ/m3.K	J/m3.K		1000.
BTU/lbmol	J/mol	British thermal units per pound-moles	2.326E3
BTU/mol	J/mol		1055.056
cal(th)/mol	J/mol		4.184
cal/kmol	J/mol		4.1868E3
cal/mol	J/mol		4.1868
GJ/kmol	J/mol		1.0E12
J/kmol	J/mol		0.001
J/mol	J/mol		1.
kcal(th)/mol	J/mol		4.184E3
kcal/kmol	J/mol		4.1868
kcal/mol	J/mol		4.1868E3
kJ/kmol	J/mol		1.0
kJ/mol	J/mol		1000.
MJ/kmol	J/mol		1000.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
MMBTU/lbmol	J/mol		2.32444E6
MMkcal/mol	J/mol		4.1868E9
BTU/lbmol.degF	J/mol.K		4.1868
BTU/lbmol.Rnk	J/mol.K		4.1868
BTU/mol.F	J/mol.K		1.8991006E3
BTU/mol.Rnk	J/mol.K		1.8991006E3
cal(th)/mol.K	J/mol.K		4.184
cal/kmol.degC	J/mol.K		4.1868E3
cal/kmol.K	J/mol.K		4.1868E3
cal/mol.degC	J/mol.K		4.1868
cal/mol.K	J/mol.K		4.1868
cal/mol.K	J/mol.K		4.1868
J/kmol.degC	J/mol.K		0.001
J/kmol.K	J/mol.K		0.001

J/mol.degC	J/mol.K		1.
J/mol.K	J/mol.K		1
kcal/kmol.degC	J/mol.K		4.1868
kcal/kmol.K	J/mol.K		4.1868
kcal/mol.degC	J/mol.K		4.1868E3
kcal/mol.K	J/mol.K		4.1868E3
kJ/kmol.degC	J/mol.K		1.
kJ/kmol.K	J/mol.K		1.
kJ/mol.degC	J/mol.K		1000.
kJ/mol.K	J/mol.K		1.E3
BTU/lbmol.Rnk2	J/mol.K2		7.53624
cal(th)/mol.K2	J/mol.K2		4.184
cal/mol.K2	J/mol.K2		4.1868
J/mol.K2	J/mol.K2		1.
kcal/kmol.K2	J/mol.K2		4.1868
kJ/kmol.K2	J/mol.K2		1.
kJ/mol.K2	J/mol.K2		1000.
cal(th)/mol.K3	J/mol.K3		4.184
cal/mol.K3	J/mol.K3		4.1868
J/mol.K3	J/mol.K3		1.
kJ/mol.K3	J/mol.K3		1000.
cal(th)/mol.K4	J/mol.K4		4.184
J/mol.K4	J/mol.K4		1.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
cal/mol.atm	J/mol.Pa		4.13205E-5
J/mol.Pa	J/mol.Pa		1.
cal/mol.Torr.K	J/mol.Pa.K		0.0314035751
J/mol.Pa.K	J/mol.Pa.K		1.
BTU/hr	J/s		0.29307107
cal/hr	J/s		1.163E-3
cal/s	J/s		4.1868
GJ/hr	J/s		2.7777778E5
J/s	J/s		1.
kcal/hr	J/s		1.1629833
kJ/hr	J/s		0.2777777778
kJ/min	J/s		16.666667
kJ/s	J/s		1.0E3

MJ/hr	J/s		277.77778
MMBTU/day	J/s		1.221129458E4
MMBTU/hr	J/s		0.29307107E6
MMkcal/day	J/s		4.84576375E4
MMkcal/hr	J/s		1.1629833E6
BTU/hr.degF	J/s.K		0.52753056
BTU/hr.Rnk	J/s.K		.527527926
cal/s.K	J/s.K		4.1868
J/s.K	J/s.K		1.
kcal/hr.K	J/s.K		1.1629833
kcal/s.K	J/s.K		4186.8
kJ/hr.degC	J/s.K		0.27777778
kJ/s.degC	J/s.K		1.0E3
kJ/s.K	J/s.K		1.0E3
kcal/hr.m2	J/s.m2		1.1629833
kJ/hr.m2	J/s.m2		0.2777777778
kJ/s.m2	J/s.m2		1000.
kJ/s.m2.K	J/s.m2		1.0E3
kcal/hr.m2.degC	J/s.m2.K		1.1629833
kcal/hr.m2.K	J/s.m2.K		1.1629833
kcal/s.m2.K	J/s.m2.K		4186.8
kJ/hr.m2.degC	J/s.m2.K		0.2777777778
kJ/s.m2.degC	J/s.m2.K		1000.
degC	K	degrees centigrade	1. (+273.15)

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
degF	K		0.55555556 (+255.37222)
K	K		1.
kK	K		1000.
mK	K		0.001
Reamur	K		1.25 (+273.15)
Rnk	K		0.55555556
degF/psia	K/Pa		8.05764E-5
K/atm	K/Pa		9.86923E-6
K/bar	K/Pa		1.E-5
K/MPa	K/Pa		1.E-6
K/Pa	K/Pa		1.
degC-1	K-1		1.

degF-1	K-1		1.8
K-1	K-1		1.
Rnk-1	K-1		1.8
K2	K2		1.
degF2/lbmol2	K2/mol2		1.500111E-6
degF2/lbmol3	K2/mol3		3.3071795E-9
K2/Pa	K2/Pa		1.
K2/Torr	K2/Pa		7.500615E-3
K3	K3		1.
g	kg		0.001
kg	kg		1.
lb	kg	pound avdp.	0.45359237
Mlb	kg	1000 pounds (avdp)	453.59237
ton	kg		1000.
ton(long)	kg		1016.0469
ton(short)	kg		907.18474
kg.m2	kg.m2		1.
lb.in2	kg.m2		2.9263961E-4
g/cycle	kg/cycle		0.001
kg/cycle	kg/cycle		1.
lb/cycle	kg/cycle		0.45359237
Mlb/cycle	kg/cycle		453.59237
ton(short)/cycle	kg/cycle		907.18474
ton/cycle	kg/cycle		1000.
kg/J	kg/J		1.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
g/100g solvent	kg/kg solvent		0.01
g/kg solvent	kg/kg solvent		0.001
kg/kg solvent	kg/kg solvent	kg solute per kg solvent	1.
mg/kg solvent	kg/kg solvent		1.E-6
kg/m	kg/m		1.
lb/ft	kg/m		1.4881639
kg/m.hr	kg/m.s		2.7777778E-4
slug/hr.ft	kg/m.s		0.013268619
kg/m.hr2	kg/m.s2		7.7160494E-8
kg/m.s2	kg/m.s2		1.
lb/in.s2	kg/m.s2		17.857967

lb/m.s2	kg/m.s2		0.45359237
g.cm2	kg/m2		10.
kg/cm2	kg/m2		1.E-4
kg/m2	kg/m2		1.
lb.ft2	kg/m2		0.04214
poundals/ft2	kg/m2		0.15175047
kg/m2.atm.hr	kg/m2.Pa.s		2.7414535E-9
lb/ft2.atm.hr	kg/m2.Pa.s		1.3384948E-8
g/cm2.s	kg/m2.s		10.
kg/m2.hr	kg/m2.s		2.7777778E-4
kg/m2.s	kg/m2.s		1.
lb/ft2.hr	kg/m2.s		1.3562298E-3
lb/ft2.s	kg/m2.s		4.8824276
g/cm2.s.atm	kg/m2.s.Pa		9.8692326E-5
g/cm2.s.Pa	kg/m2.s.Pa		10.
kg/m2.s.Pa	kg/m2.s.Pa		1.
g/100ml	kg/m3		10.
g/cm3	kg/m3		1000.
g/dm3	kg/m3		1.
g/l	kg/m3		1.
g/m3	kg/m3		1.E-3
g/ml	kg/m3		1.E3
kg/cm3	kg/m3		1.E6
kg/dm3	kg/m3		1.E3
kg/l	kg/m3		1.E3
kg/m3	kg/m3		1.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
lb/ft3	kg/m3		16.018463
lb/gal	kg/m3		119.82643
lb/in3	kg/m3		27.6799E3
mg/cm3	kg/m3		1.
mg/l	kg/m3		1.E-3
mg/m3	kg/m3		1.E-6
g/100cm3 solvent	kg/m3 solvent		10.
g/l solvent	kg/m3 solvent		1.
kg/m3 solvent	kg/m3 solvent	kg solute per m3 solvent	1.
kg/m3(0 C, 1 atm)	kg/m3(0 C, 1 atm)	kg per norm cubic m	1.

g/cm3.K	kg/m3.K		1.E3
kg/m3.K	kg/m3.K		1.
g/mol	kg/mol		0.001
kg/mol	kg/mol		1.
lb/lb(force).hr.ft2	kg/N.s.m2		3.0489259E-4
g/atm.hr	kg/Pa.s		2.7414535E-6
g/bar.hr	kg/Pa.s		2.7777778E-6
g/kPa.hr	kg/Pa.s		2.7777778E-4
g/kPa.min	kg/Pa.s		1.6666667E-8
g/kPa.s	kg/Pa.s		1.E-6
g/mmHg.hr	kg/Pa.s		2.0835042E-3
kg/atm.hr	kg/Pa.s		2.7414535E-9
kg/atm.s	kg/Pa.s		9.8692327E-6
kg/bar.hr	kg/Pa.s		2.77777778E-9
kg/bar.s	kg/Pa.s		1.E-5
kg/cmH2O.hr	kg/Pa.s		2.8326244E-6
kg/kPa.hr	kg/Pa.s		2.77777778E-7
kg/kPa.min	kg/Pa.s		1.66666667E-5
kg/kPa.s	kg/Pa.s		1.E-3
kg/mmH2O.hr	kg/Pa.s		2.8326244E-7
kg/mmHg.hr	kg/Pa.s		2-0835042E-6
kg/Pa.hr	kg/Pa.s		2.77777778E-4
lb/atm.hr	kg/Pa.s		1.2435024E-9
lb/atm.s	kg/Pa.s		4.4766086E-6
lb/inH2O.hr	kg/Pa.s		5.0585892E-7
lb/inHg(32F).hr	kg/Pa.s		3.7207138E-8
lb/psi.hr	kg/Pa.s		1.827444E-8

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
lb/psi.min	kg/Pa.s		1.0964664E-6
lb/psi.s	kg/Pa.s		6.5787985E-5
g/s	kg/s		1.E-3
kg/day	kg/s		1.157407417E-5
kg/hr	kg/s		0.27777778E-3
kg/min	kg/s		0.0166666667
kg/s	kg/s		1.
lb/day	kg/s		5.249911667E-6
lb/hr	kg/s		0.12599788E-3

lb/s	kg/s		453.59237E-3
Mlb/hr	kg/s	1000 pounds (avdp) per hour	0.12599788
ton/day	kg/s		0.0115741
ton/hr	kg/s		0.27777778
ton/year	kg/s		3.1709792E-5
kg/kW.hr	kg/W.hr		2.777778E-7
lb/hp.hr	kg/W.s		1.689659E-7
kg-1.m-1.s-1	kg-1.m-1.s-1		1.
kJ/cycle	kJ/cycle		1000.
l/Val	l/Val		1.
Ang	m	Angstrøm	1.E-10
cm	m		0.01
dm	m		0.1
ft	m		0.3048
in	m		0.0254
km	m		1000.
m	m		1.
micron	m		1.E-6
mile	m		1609.344
mm	m		1.E-3
nm	m		1.E-9
um	m	mikro-meter	1.E-6
yd	m		0.9144
m/K	m/K		1.
ft/lb	m/kg		6.719690E-1
m/kg	m/kg		1.
bbl/ft2.hr	m/s	barrel per square foot and hour	4.7535474E-4
cm/hr	m/s		2.7777778E-6

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
cm/s	m/s		0.01
cm2/cm.s	m/s		0.01
ft/hr	m/s		8.46666667E-5
ft/min	m/s		5.08E-3
ft/s	m/s		0.3048
ft2/ft.hr	m/s		8.4666667E-5
ft2/ft.s	m/s		0.3048
ft3/ft2.s	m/s		0.3048

ft3/ft2.hr	m/s		8.46666667E-5
gal/ft2.min	m/s		6.79097E-4
km/hr	m/s		0.27777778
km/s	m/s		1000.
l/m2.hr	m/s		2.7778E-7
l/m2.s	m/s		1.E-3
m/hr	m/s		2.77777778E-4
m/min	m/s		0.0166666667
m/s	m/s		1.
m/s	m/s		1.
m2/m.hr	m/s		2.7777778E-4
m2/m.s	m/s		1.
m3/m2.s	m/s		1.
m3/m2.min	m/s		1.6666667E-2
mile/hr	m/s		0.44704
l/hr.rpm	m/s.rpm		2.7777778E-7
m3/min.rpm	m/s.rpm		1.6666667E-2
cm-1	m-1		100.
cm2/cm3	m-1		100.
ft-1	m-1		3.280840
ft2/ft3	m-1		3.2808
in-1	m-1		39.370079
in2/in3	m-1		0.39370079
m-1	m-1		1.
m2/m3	m-1		1.
mm-1	m-1		1000.0
mm2/mm3	m-1		1000.
m-1.s-2	m-1.s-2		1.
cm12/mol4	m12/mol4		1.E-24

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
l4/mol4	m12/mol4		1.E-12
m12/mol4	m12/mol4		1.
cm15/mol5	m15/mol5		1.E-30
m15/mol5	m15/mol5		1.
ft-2	m-2		10.76364864
cm2	m2		1.E-4
dm2	m2		0.01

ft2	m2		0.09290304
in2	m2		0.00064516
m2	m2		1.
mm2	m2		1.E-6
nm2	m2		1.E-18
m2.K/kW	m2.K/W		1.0E-3
m2.K/W	m2.K/W		1.
m2/g	m2/kg		0.001
m2/kg	m2/kg		1.
ft2/lb(force)	m2/N		2.0885434E-2
m2/Ohm	m2/Ohm		1.
cm2/Ohm.mol	m2/Ohm.mol		1.E-4
m2/Ohm.mol	m2/Ohm.mol		1.
Sie.cm2/mol	m2/Ohm.mol		0.01
cm2/Ohm.val	m2/Ohm.val		1.E-4
m2/Ohm.val	m2/Ohm.val		1.
bbl/ft.hr	m2/s	barrel/(foot and hour)	9.1134442E-4
cm2/s	m2/s		1.E-4
cSt	m2/s	centistokes	1.E-6
ft2/hr	m2/s		2.58064E-5
ft2/min	m2/s		1.548385E-3
ft3/ft.hr	m2/s		2.58064E-5
l/hr.m	m2/s		2.7777778E-7
m2/day	m2/s		1.1574074E-5
m2/hr	m2/s		2.7777778E-4
m2/s	m2/s		1.
m2/year	m2/s		3.1688087E-8
m3/m.min	m2/s		1.6666667E-2
m3/m.s	m2/s		1.
mm2/s	m2/s		1.E-6

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
mSt	m2/s		1.E-7
St	m2/s		1.E-4
cm2/s.mol fraction	m2/s.mol fraction		1.
m2/s.mol fraction	m2/s.mol fraction		1.
m2/s2	m2/s2		1.
cm2/V.s	m2/V.s		1.E-4

m2/V.s	m2/V.s		1.
bbl	m3	barrel	0.15898729
cm3	m3		1.0E-6
dm3	m3		1.E-3
ft3	m3		2.8316847E-2
gal	m3		3.7854118E-3
in3	m3		1.6387064E-5
l	m3	liters	1.E-3
m3	m3		1.
ml	m3		1.E-6
cm3.K/mol	m3.K/mol		1.E-6
ft3.Rnk/lbmol	m3.K/mol		3.468220043E-5
m3.K/kmol	m3.K/mol		1.E-3
bbl/cyle	m3/cycle	barrel/cycle	0. 15898729
ft3/cycle	m3/cycle		2.8316847E-2
gal/cycle	m3/cycle		3.7854118E-3
kbbl/cycle	m3/cycle	1000 barrels per cycle	0.15898729
l/cycle	m3/cycle		0.001
m3/cycle	m3/cycle		1.
MMft3/cycle	m3/cycle	million cubic feet per cycle	2.8316847E4
kbbl/day	m3/day		1.840131E-6
cm3/kg	M3/g		1.E-3
m3/K	m3/K		1.
cm3/100g	m3/kg		1.E-5
cm3/g	m3/kg		1.E-3
dm3/g	m3/kg		1.
dm3/kg	m3/kg		1.E-3
ft3/lb	m3/kg		0.062427962
l/g	m3/kg		1.
l/kg	m3/kg		1.E-3
m3/kg	m3/kg		1.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
ml/g	m3/kg		1.E-3
cm3/g solvent	m3/kg solvent		1.E-3
m3/kg solvent	m3/kg solvent		1.
m3/kg.s	m3/kg.s		1.
m3/kg.s2	m3/kg.s2		1.

cm3/cm3 solvent	m3/m3 solvent		1.
cm3/l solvent	m3/m3 solvent		1.E-3
l/l solvent	m3/m3 solvent		1.
m3/m3 solvent	m3/m3 solvent		1.
ml/ml solvent	m3/m3 solvent		1.
cm3/cm3(sat.solut.)	m3/m3(sat.solution)		1.
cm3/l.atm	m3/m3.Pa		0.0098692327E-6
m3/m3.Pa	m3/m3.Pa		1.
dm3/mol	m3/mol		1.E-3
ft3/lbmol	m3/mol		6.242796029E-5
l/mol	m3/mol		1.E-3
m3/kmol	m3/mol		0.001
m3/mol	m3/mol		1.
ml/mol	m3/mol		1.E-6
cm3/mol2	m3/mol2		1.E-6
cm3/bar.g	m3/Pa.kg		1.E-8
m3/Pa.kg	m3/Pa.kg		1.
bbl/psi.hr	m3/Pa.s	barrel/(pounds per square inch and hour)	6.4053188E-9
ft3/psia.min	m3/Pa.s		6.8450163E-8
ft3/psia.s	m3/Pa.s		4.107010E-6
l/atm.hr	m3/Pa.s		2.7414535E-12
l/kPa.hr	m3/Pa.s		2.7777778E-10
l/mmHg.hr	m3/Pa.s		2.0835042E-9
m3/kPa.hr	m3/Pa.s		2.7777778E-7
m3/kPa.min	m3/Pa.s		1.6666667E-5
m3/kPa.s	m3/Pa.s		1.E-3
ml/atm.hr	m3/Pa.s		2.7414535E-15
ml/kPa.hr	m3/Pa.s		2.7777778E-13
bbl/day	m3/s	barrel/day	1.8401307E-6
bbl/hr	m3/s	barrel/hour	0.04415E-3
ft3/day	m3/s		3.2774128E-7
ft3/hr	m3/s		7.8657907E-6

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
ft3/min	m3/s		4.7194744E-4
ft3/s	m3/s		0.028316846
gal/hr	m3/s		1.0515033E-6

gal/min	m3/s		6.3090196E-5
l/day	m3/s		1.157407E-8
l/hr	m3/s		2.7777778E-7
l/min	m3/s		1.6666667E-5
l/s	m3/s		0.001
l/year	m3/s		3.1688087E-11
m3/day	m3/s		1.1574074E-5
m3/hr	m3/s		2.7777778E-4
m3/min	m3/s		1.6666667E-2
m3/s	m3/s		1.
m3/year	m3/s		3.1688087E-8
Mft3/day	m3/s	1000 cubic feet per day	0.327741279E-3
MMft3/day	m3/s	million cubic feet per day	0.327741279
MMft3/hr	m3/s	million cubic feet per hour	7.8657907
cm3/hr.K	m3/s.K		2.7777778E-10
l/min.m	m3/s.m		1.6666667E-5
l/s.m	m3/s.m		0.001
m3/hr.m	m3/s.m		2.7777778E-4
l/min.m2	m3/s.m2		1.6666667E-5
l/s.m2	m3/s.m2		0.001
m3/hr.m2	m3/s.m2		2.7777778E-4
ft3/hr.psi	m3/s.Pa		1.140836E-9
ft3/min.rpm	m3/s.rpm		4.7194744E-4
ft3/s.rpm	m3/s.rpm		0.028316846
gal/hr.rpm	m3/s.rpm		1.0515033E-6
gal/min.rpm	m3/s.rpm		6.3090196E-5
l/day.rpm	m3/s.rpm		1.157407E-8
l/min.rpm	m3/s.rpm		1.6666667E-5
l/s.rpm	m3/s.rpm		0.001
m3/day.rpm	m3/s.rpm		1.1574074E-5
m3/hr.rpm	m3/s.rpm		0.2777778E-3
m3/s.rpm	m3/s.rpm		1.
m3/year.rpm	m3/s.rpm		3.1688087E-8
ft3/s2	m3/s2		0.028316846

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
m3/s2	m3/s2		1.

cm2.l/Ohm.mol2	m5/Ohm.mol2	square cm*liters per Ohm and mole squared	1.E-7
m5/Ohm.mol2	m5/Ohm.mol2		1.
cm2.l/s.mol	m5/s.mol		1.E-7
m5/s.mol	m5/s.mol		1.
cm6/mol2	m6/mol2		1.E-12
dm6/mol2	m6/mol2		1.E-6
ft6/lbmol2	m6/mol2		3.8972502E-9
l2/mol2	m6/mol2		1.E-6
m6/mol2	m6/mol2		1.
cm9/mol3	m9/mol3		1.E-18
dm9/mol3	m9/mol3		1.E-9
ft9/lbmol3	m9/mol3		2.4329738E-13
l3/mol3	m9/mol3		1.E-9
m9/mol3	m9/mol3		1.
mass fraction	mass fraction		1.
kmol	mol		1000.
lbmol	mol	pound-mole	453.592368
mol	mol		1.
mol %	mol fraction		1.E-2
mol fraction	mol fraction		1.
mol/mol	mol fraction		1.
kmol/cycle	mol/cycle		1000.
lbmol/cycle	mol/cycle		453.59237
mol/cycle	mol/cycle		1.E-3
lbmol/day	mol/day		5.249911667E-3
lbmol/day.ft	mol/day.m		1.722412E-2
mol/100g	mol/kg		10.
mol/kg	mol/kg		1.
molon	mol/kg		1.
umol/100 g	mol/kg	micro-mol per 100 grams	1.E-5
mol/m.min	mol/m.s		1.6666667E-2
mol/m.s	mol/m.s		1.
dmol/m3	mol/m3		0.1
kmol/m3	mol/m3		1.E3
lbmol/ft3	mol/m3		1.6018463E4
lbmol/gal	mol/m3		1.1982643E5

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
mmol/cm3	mol/m3		0.001
mmol/l	mol/m3		1.
mol/cm3	mol/m3		1.E6
mol/dm3	mol/m3		1.E3
mol/l	mol/m3		1.E3
mol/m3	mol/m3		1.
mol/l solvent	mol/m3 solvent		1000.
mol/m3 solvent	mol/m3 solvent		1.
mol/m3.K	mol/m3.K		1.
kmol/m3.atm	mol/m3.Pa		9.86923E-3
mol/m3.atm	mol/m3.Pa		9.86923E-6
mol/m3.Pa	mol/m3.Pa		1.
lbmol/ft3.hr	mol/m3.s		4.4495732
lbmol/ft3.min	mol/m3.s		2.6697439E2
lbmol/ft3.s	mol/m3.s		1.6018563E4
mol/cm3.hr	mol/m3.s		3.6E9
mol/cm3.s	mol/m3.s		1.E6
mol/l.hr	mol/m3.s		0.277777778
mol/l.s	mol/m3.s		1.E3
mol/mol solvent	mol/mol solvent		1.
lbmol/atm.s	mol/Pa.s		0.0044766086
lbmol/psi.min	mol/Pa.s		1.0964664E-3
lbmol/psi.s	mol/Pa.s		6.5787985E-2
mol/atm.hr	mol/Pa.s		2.7414535E-9
mol/bar.hr	mol/Pa.s		2.7777778E-9
mol/kPa.hr	mol/Pa.s		2.7777778E-7
mol/kPa.min	mol/Pa.s		1.66666667E-5
mol/kPa.s	mol/Pa.s		1.E-3
kmol/day	mol/s		1.157407417E-5
kmol/hr	mol/s		0.27777778
kmol/s	mol/s		0.001
lbmol/hr	mol/s		0.12599788
lbmol/s	mol/s		0.45359237E3
mol/min	mol/s		1.6666667E-2
mol/s	mol/s		1.E-3
kmol/day.m	mol/s.m		1.157407417E-5
kmol/hr.m	mol/s.m		0.27777778E-6

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
kmol/s.m	mol/s.m		0.001
lbmol/hr.ft	mol/s.m		0.41337887
lbmol/s.ft	mol/s.m		1.4881639E3
kmol/hr.m3	mol/s.m3		0.27777778E-6
kmol/s.m3	mol/s.m3		0.001
kmol/hr.atm	mol/s.Pa		2.7414535E-6
kmol/hr.bar	mol/s.Pa		2.77777778E-6
kmol/hr.kPa	mol/s.Pa		2.77777778E-4
kmol/hr.mmH2O	mol/s.Pa		0.0283262437
kmol/hr.Pa	mol/s.Pa		0.27777778
kmol/min.kPa	mol/s.Pa		0.0166666667
kmol/s.atm	mol/s.Pa		9.8692327E-9
kmol/s.bar	mol/s.Pa		1.E-8
kmol/s.kPa	mol/s.Pa		1.E-6
mol-1	mol-1		1.
mol2/l2	mol2/m6		1.E6
mol2/m6	mol2/m6		1.
mol/100g solvent	molal		10.
mol/g solvent	molal		1000.
mol/kg solvent	molal		1.
molal	molal		1.
molal-1	molal-1		1.
molar	molar		1.
dyn	N		1.0E-5
lb(force)	N		4.4482216
N	N		1.
dyn^(1/4).cm^(11/4)/ml	N^(1/4).m^(11/4)/mol		1.7782794E-7
N^(1/4).m^(11/4)/mol	N^(1/4).m^(11/4)/mol		1.
lb(force).ft	N.m		1.3558179
lb(force).ft/lb	N.m/kg		2.989067
lb(force).ft/s	N.m/s		1.3558179
mN.s/m2	N.s/m2		0.001
dyn/cm	N/m		1.E-3
lb(force)/ft	N/m		14.593903
mN/m	N/m		1.E-3
N/m	N/m		1.

N/m2.m	N/m		1.

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
lb(force)/ft2	N/m2		47.880259
lb(force)/ft3	N/m3		157.08747
mmH2O/m	N/m3		9.806348
N/m3	N/m3		1.
Ohm	Ohm		1.
Ohm.cm	Ohm.m		0.01
Ohm.m	Ohm.m		1.
Ohm-1	Ohm-1		1.
Ohm-1.cm-1	Ohm-1.m-1		100.
Ohm-1.m-1	Ohm-1.m-1		1.
Sie/cm	Ohm-1.m-1		100.
Sie/m	Ohm-1.m-1		1.
Ohm-1.m-3	Ohm-1.m-3		1.
Sie/ml	Ohm-1.m-3		1.E6
ata	Pa	absolute atmospheres	98066.5
atm	Pa		101325.
bar	Pa		1.E5
cmH2O	Pa	cm of water column (pressure)	98.063754
Gpa	Pa		1.E9
Hpa	Pa		100.
inH2O	Pa	inches of water columns (pressure)	249.0889
inHg(32F)	Pa		3386.39
inHg(60F)	Pa		3332.69
kbar	Pa		1.E8
kg(force)/cm2	Pa		98066.5
kN/m2	Pa		1000.
kp/cm2	Pa		98066.5
kp/m2	Pa		9.80665
kPa	Pa		1.E3
lb(force)/in2	Pa		6.89476E3
lb/in2	Pa		6.89476E3
mbar	Pa		100.
mmH2O	Pa	mm of water column	9.806348
mmHg	Pa	mm of Hg column (Torr)	133.3223684

MN/m2	Pa		1.E6
mPa	Pa		1.E-3
MPa	Pa		1.E6

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
mTorr	Pa		0.1333224
N/m2	Pa		1.
Pa	Pa		1.
psi	Pa	pounds per square inch	6894.7573
Torr	Pa		133.3224
ata.K	Pa.K		98066.5
atm.K	Pa.K		101325.
kPa.K	Pa.K		1000.
Pa.K	Pa.K		1.
kg(force).m/kg	Pa.m/kg		9.80665
bar.m/s	Pa.m/s		1.E5
Pa.m/s	Pa.m/s		1.
atm.ft3/lbmol	Pa.m3/mol		6.3255133
Pa.cm3/mol	Pa.m3/mol		1.E6
Pa.dm3/mol	Pa.m3/mol		1.E3
Pa.m3/mol	Pa.m3/mol		1.
psi.ft6	Pa.m6		5.5285184
atm.dm6.K/mol2	Pa.m6.K/mol2		0.101325
Pa.m6.K/mol2	Pa.m6.K/mol2		1.
atm.l2.K2/mol2	Pa.m6.K2/mol2		0.101325
bar.m6.K2/mol2	Pa.m6.K2/mol2		1.E5
kPa.m6.K2/mol2	Pa.m6.K2/mol2		1000.
Pa.m6.K2/mol2	Pa.m6.K2/mol2		1.
bar.cm6/g.K	Pa.m6/kg.K		1.E2
Pa.m6/kg.K	Pa.m6/kg.K		1.
atm.l2/mol2	Pa.m6/mol2		0.101325
kPa.m6/mol2	Pa.m6/mol2		1000.
Pa.m6/mol2	Pa.m6/mol2		1.
psi.ft6/lbmol2	Pa.m6/mol2		2.68706E-5
psi.ft9	Pa.m9		0.15655021
kPa.m9.K2/mol3	Pa.m9.K2/mol3		1000.
kPa.m9/mol3	Pa.m9/mol3		1000.
Pa.m9/mol3	Pa.m9/mol3		1.

psi.ft9/lbmol3	Pa.m9/mol3		1.6774764E-9
kbar.mol.K/cm3	Pa.mol.K/m3		1.E14
Pa.mol.k/m3	Pa.mol.K/m3		1.
cP	Pa.s	centipoise	0.001

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
g/cm.s	Pa.s		0.1
kg(force).s/m2	Pa.s		9.80665
kg/m.s	Pa.s		1.
kp.s/m2	Pa.s		9.807
lb(force).s/ft2	Pa.s		47.880262
lb/ft.hr	Pa.s		4.1337887E-4
lb/ft.s	Pa.s		1.48816
mP	Pa.s		1.E-4
mPa.s	Pa.s		1.E-3
N.s/m2	Pa.s		1.
P	Pa.s		0.1
Pa.s	Pa.s		1.
psi.hr	Pa.s		2.4821136E7
ug/cm.s	Pa.s	mico-gram per cm and s	1.E-7
uP	Pa.s	micropoise	1.E-7
uPa.s	Pa.s	micro-Pascal-seconds	1.E-6
mPa.s.cm3/g	Pa.s.m3/kg		1.E-6
Pa.s.m3/kg	Pa.s.m3/kg		1.
uPa.s.cm3/g	Pa.s.m3/kg	micro-Pascal.s.cm3/g	1.E3
Pa.s/K	Pa.s/K		1.
Pa.s/K2	Pa.s/K2		1.
Pa.s/K3	Pa.s/K3		1.
cP/mol %	Pa.s/mol fraction		0.1
cP/mol fraction	Pa.s/mol fraction		0.001
Pa.s/mol fraction	Pa.s/mol fraction		1.
lb/ft.hr2	Pa.s2		1.1482746E-7
lb/ft.s2	Pa.s2		1.4881662
ata/K	Pa/K		98066.5
atm/K	Pa/K		101325.
bar/K	Pa/K		1.E5
kbar/K	Pa/K		1.E8
kPa/K	Pa/K		1.E3

mbar/K	Pa/K		1.E2
mPa/K	Pa/K		1.E-3
MPa/K	Pa/K		1.E6
Pa/K	Pa/K		1.
psi/F	Pa/K		12410.568

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
Torr/K	Pa/K		133.3224
ata/m	Pa/m		98066.5
atm/m	Pa/m		101325.
bar/km	Pa/m		100.
bar/m	Pa/m		1.E5
cmH2O/m	Pa/m		98.063754
inH2O/ft	Pa/m		817.2208
inHg(32F)/ft	Pa/m		11110.203
kPa/km	Pa/m		1.E6
kPa/mm	Pa/m		1.
mbar/m	Pa/m		1.E2
mH2O/m	Pa/m		98.063754
mmHg/ft	Pa/m		437.4094
Pa/m	Pa/m		1.
psi/100ft	Pa/m		2.2620595E2
psi/ft	Pa/m		2.2620595E4
Torr/ft	Pa/m		437.40945
kbar/cm3.mol	Pa/m3.mol		1.E14
Pa/m3.mol	Pa/m3.mol		1.
ata/mol fraction	Pa/mol fraction		98066.5
atm/mol fraction	Pa/mol fraction		101325.
bar/mol fraction	Pa/mol fraction		1.E5
kPa/mol fraction	Pa/mol fraction		1.E3
MPa/mol fraction	Pa/mol fraction		1.E6
Pa/(mol/mol)	Pa/mol fraction		1.
Pa/mol fraction	Pa/mol fraction		1.
psi/mol fraction	Pa/mol fraction		6894.76
Torr/mol fraction	Pa/mol fraction		133.3224
ata/s	Pa/s		98066.5
atm/s	Pa/s		101325.
bar/s	Pa/s		1.E5

Pa/s	Pa/s		1.
atm/weight fraction	Pa/weight fraction		101325.
Pa/weight fraction	Pa/weight fraction		1.
MPa^0.5	Pa^0.5		1.E3
Pa^0.5	Pa^0.5		1.
ata-1	Pa-1		1.01972E-5

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
atm-1	Pa-1		9.86923E-6
bar-1	Pa-1		1.E-5
cm2/dyn	Pa-1		10.
cm2/kg(force)	Pa-1		1.0197162E-5
cm2/kp	Pa-1		1.01972E-5
Gpa-1	Pa-1		1.E-9
inH2O-1	Pa-1		4.0146309E-3
kbar-1	Pa-1		1.E-8
kPa-1	Pa-1		1.E-3
m2/kp	Pa-1		0.101972
m2/N	Pa-1		1.
mbar-1	Pa-1		1.E-2
mmH2O-1	Pa-1		0.1019748
mPa-1	Pa-1		1.E3
MPa-1	Pa-1		1.E-6
Pa-1	Pa-1		1.
psi-1	Pa-1		1.4503774E-4
Torr-1	Pa-1		7.500615E-3
TPa-1	Pa-1		1.E-12
atm-1.K-1	Pa-1.K-1		9.86923E-6
Pa-1.K-1	Pa-1.K-1		1.
P-1	Pa-1.s-1		10.
Pa-1.s-1	Pa-1.s-1		1.
ata-2	Pa-2		1.0398289E-10
atm-2	Pa-2		9.7401753E-11
bar-2	Pa-2		1.E-10
kPa-2	Pa-2		1.E-6
mbar-2	Pa-2		1.E-4
Pa-2	Pa-2		1.
Torr-2	Pa-2		5.6259226E-5

ata-3	Pa-3		1.0603225E-15
atm-3	Pa-3		9.6128057E-16
bar-3	Pa-3		1.E-15
kPa-3	Pa-3		1.E-9
mbar-3	Pa-3		1.E-6
Pa-3	Pa-3		1.
Torr-3	Pa-3		4.219788E-7

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
ata-4	Pa-4		1.081228E-20
atm-4	Pa-4		9.4871016E-21
bar-4	Pa-4		1.E-20
kPa-4	Pa-4		1.E-12
mbar-4	Pa-4		1.E-8
Pa-4	Pa-4		1.
Torr-4	Pa-4		3.1651005E-9
day	s		86400.
hr	s		3600.
min	s		60.
ms	s		0.001
ns	s		1.E-9
ps	s		1.E-12
s	s		1.
us	s	microseconds	0.000001
year	s		31536000.
hr.ft2.Rnk/BTU	s.m2.K/J		1.7611019E-1
hr.m2.K/kcal	s.m2.K/J		8.5984523E-1
s.cm2.K/cal	s.m2.K/J		2.3884590E-5
s.m2.K/J	s.m2.K/J		1.0
s.m2.K/kcal	s.m2.K/J		2.3884590E-4
s.m2.K/kJ	s.m2.K/J		1.0E-3
day-1	s-1		1.1574074E-5
GHz	s-1		1.E9
kHz	s-1		1000.
MHz	s-1		1000000.
rad/s	s-1		0.15915475
year-1	s-1		3.1688088E-8
kV	V		1.E3

mV	V		1.E-3
V	V		1.
V/cm	V/m		100.
V/m	V/m		1.
val/kg	val/kg		1.
val/l	val/m3		1.E3
val/m3	val/m3		1.
cm3/100cm3	volume fraction		0.01

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
cm3/cm3	volume fraction		1.
cm3/l	volume fraction		1.E-3
l/m3	volume fraction		1.E-3
m3/m3	volume fraction		1.
ml/m3	volume fraction		1.E-6
volume %	volume fraction		0.01
volume fraction	volume fraction		1.
BTU/s	W		1.0550559E3
erg/s	W		1.E-7
hp	W	hourse power	745.69987
kcal/s	W		4.1868E3
kp.m/s	W		9.80665
kW	W		1000.
PS	W		745.700
W	W		1.
hp.hr	W.s		2.6845195E6
kW/cycle	W/cycle		1000.
W/cycle	W/cycle		1.
W/degC	W/K		1
W/K	W/K		1.
W/kg	W/kg		1.
W/m	W/m		1.
BTU.in/ft2.hr.degF	W/m.K		0.14422789
BTU.in/ft2.hr.Rnk	W/m.K		0.14422789
BTU/ft.hr.degF	W/m.K		1.7307347
BTU/ft.s.degF	W/m.K		6230.6449
BTU/in.hr.degF	W/m.K		20.768816
BTU/in.s.degF	W/m.K		7.4767738E4

cal/cm.s.K	W/m.K		4.1868E2
cal/km.s.K	W/m.K		4.1868E-3
cal/m.hr.K	W/m.K		1.163E-3
cal/m.s.K	W/m.K		4.1868
erg/cm.s.K	W/m.K		1.E-5
J/cm.s.K	W/m.K		1.E2
J/m.s.K	W/m.K		1.
kcal.m/hr.m2.K	W/m.K		1.163
kcal/m.hr.K	W/m.K		1.163

unit	SI-unit	remarks	factor unit -> SI-unit (only for information)
kcal/m.s.K	W/m.K		4.1868E3
kW/m.K	W/m.K		1.0E3
mW/cm.degC	W/m.K		0.1
mW/cm.K	W/m.K		0.1
mW/m.K	W/m.K		0.001
uW/cm.K	W/m.K	micro-Watt per cm and K	0.0001
W/cm.K	W/m.K		1.E2
W/m.K	W/m.K		1.
W/m.K2	W/m.K2		1.
W/m.K3	W/m.K3		1.
W/m.K4	W/m.K4		1.
W/m2	W/m2		1
cal/cm2.s.K	W/m2.K		4.1868E4
kW/m2.K	W/m2.K		1.0E3
W/m2.degC	W/m2.K		1.
W/m2.K	W/m2.K		1.
W/m2.s.K	W/m2.s.K		1.
hp/ft3	W/m3		2.6334143E4
kW/l	W/m3		1.E6
kW/m3	W/m3		1.E3
W/m3	W/m3		1.
W/mol	W/mol		1.
hp/lbmol.hr	W/mol.s		4.566631EE-4
hp/lbmol.s	W/mol.s		1.64398709
kW/kmol.hr	W/mol.s		2.7777778E-4
kW/kmol.s	W/mol.s		1.
g/100g	weight fraction		1.E-2

g/g	weight fraction		1.
g/kg	weight fraction		0.001
kg/kg	weight fraction		1.
mg/kg	weight fraction		1.E-6
ppm	weight fraction		1.E-6
weight %	weight fraction		1.E-2
weight fraction	weight fraction		1.

bbl = petroleum barrel, USA (42 US liquid gallons)

cal(th) = thermochemical calory

gal = liquid gallons, USA hp =

mechanical horse power lb = pound

(avdp.) oz = ounces (avdp.) u... =

mikro... m... = milli... M... = Mega...

6.1.3. Pure Component Constant Properties (CAPE-OPEN)

7 Schedule

	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
User Interface	**Graphical Drag & Drop User Interface**					
	Stream and Unit Operations Input Forms					
Units Converter	Basic Unit Conversions, T, P, Q, etc					
Basic Thermo	Component Database	Low Level Functions	Equation of State	Flash Calculations	Distillation Algorithm	
	Pure	PSat1		Bubble & Dew Points		
	Binary	CPIG		Isothermal Flash		
	Vicosity Database	HVIG		Constant H Flash		
	Thermal Conductivity	SVIG		Constant S Flash		
	Surface Tension	CPIGMX				
		HVIGMX				
		SVIGMX				
Transport Properties		Visc_L, Visc_V				
		K_L, K_V				

	Sigma		
Reactors		Stoicheometric Rate Based Equilibrium	
Other Unit Operations		Splitters Mixers Component Separator	
Equipment Sizing		Lines Drums/Vessels Trays Heat Exchangers	
Report Generation		Stream Report Unit Operations Report Other Reports	
Kernal Development			Sequencing & Solving
Flowsheet Specifcations & Optimization			Controllers, Adjust Blocks, Design-Spec, Optimizers

8 Structure Description

I. Global Variables: The following variables are GLOBAL. They are defined in the mdlThermoControl module

Variable	Description	Type	Units
N_Comp	Number of Components	Integer	---
T	Temperature	Double	K
P	Pressure	Double	Bar
Vfrac	Vapor Fraction	Double	---

ZL	Liquid Compressibility Factor	Double	---
ZV	Vapor Compressibility Factor	Double	---
HLMX	Liquid Molar Enthalpy	Double	J/gmole
HVMX	Vapor Molar Enthalpy	Double	J/gmole
HMX	Mixture Molar Enthalpy	Double	J/gmole
SLMX	Liquid Molar Entropy	Double	J/gmole.K
SVMX	Vapor Molar Enthalpy	Double	J/gmole.K
SMX	Mixture Molar Enthalpy	Double	J/gmole.K
Z()	Overall Mole Fraction	Double	---
Y()	Vapor Mole Fraction	Double	---
X()	Liquid Mole Fraction	Double	---

II. Equations of State

Every equation of state should be in a separate module. All subroutines and functions that related to the EOS should be PRIVATE (not accessible to other routines) except for the ones listed below. If the name of the equation of state is ABC, then the equation should have the following subroutines

Routine	Description	Arguments
ABCZMX	Compressibility Factor	T, P, X(), N, IPhase
ABCPHX	Fugacity Coefficients	Phi, T, P, X(), N, Z
ABCHDM	Enthalpy Departure	T, P, Z, X(), N

ABCHDM	Entropy Departure	T, P, Z, X(), N

Where

T, P and N are the temperature, pressure and number of components respectively.

IPhase = 0 is to call for a liquid compressibility factor

IPhase = 1 is to call for a vapor compressibility factor

X() containing the compositions

Z: Compressibility factor

Phi: Array for fugacity coefficients.

III. Streams

The streams are currently work in progress and will be modified as needed. The initial thinking is to define the streams in a Pascal "Record" so that the stream properties can be access as follows:

Stream(1).Temp. Stream(1).Pres, etc.

The following are the parameters stored in a stream record

Parameter	Description	Type
Tag	Stream Tag	String
Name	Stream Name	String
Source	The operation the stream is coming from	
Destination	The operation the steam is going to	
Temp	Temperature	Double

Pres	Pressure	Double
Vfrac	Vapor Fraction	Double
ZL	Liquid Compressibility Factor	Double
ZV	Vapor Compressibility Factor	Double
HLMX	Liquid Molar Enthalpy	Double
HVMX	Vapor Molar Enthalpy	Double
HMX	Mixture Molar Enthalpy	Double
SLMX	Liquid Molar Entropy	Double
SVMX	Vapor Molar Enthalpy	Double
SMX	Mixture Molar Enthalpy	Double
Z()	Overall Mole Fraction	Double
Y()	Vapor Mole Fraction	Double
X()	Liquid Mole Fraction	Double
ZM()	Overall Mass Fraction	Double
MW	Molecular Weight	Double
Flow	Molar Flow Rate	Double
MassFlow	Mass Flow Rate	Double
Has_Flow	Indicates if the steam has a flow rate	Boolean
Has_Comp	Indicates if the steam has composition	Boolean
Has_Temp	Indicates if the steam has Temperature	Boolean
Has_Pres	Indicates if the steam has Pressure	Boolean

Has_Vfrac	Indicates if the steam has Vapor Fraction	Boolean
Has_HMX	Indicates if the steam has Enthalpy	Boolean
IsSolved	Indicates if the stream is Solved	Boolean

IV. Units

The units are set by the pure component database I will be donating. The reference pressure for heats of formation and Gibbs free energy of formation in this database is 1 bar, same for heat capacity. The following is a list of all key units that will be used in the heart of the simulator. User entries should be converted to these units (e.g. steam temperature, pressure, etc) BEFORE they are stored in the appropriate location.

Property	Units
Temperature	K
Pressure	Bar
Molar Flow Rate	gmole/hr
Mass Flow Rate	grams/hr
Enthalpy	J/gmole
Entropy	J/gmole.K
Heat Duty/Power	J/hr

I agree, this is the most disgusting set of units I have ever seen but let's put up with it for now.

V.
VI.