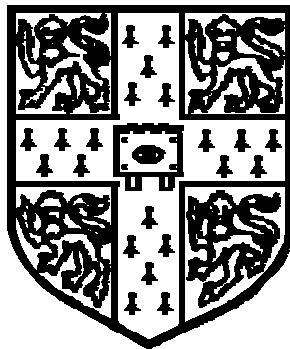


Thermofluids Data Book

for Part I of the
Engineering Tripos

2004 Edition



Cambridge University Engineering Department

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THERMODYNAMIC DEFINITIONS & RELATIONSHIPS

Specific enthalpy

$$h \equiv u + pv$$

Specific heat capacity at constant volume

$$c_v \equiv \left(\frac{\partial u}{\partial T} \right)_v$$

Specific heat capacity at constant pressure

$$c_p \equiv \left(\frac{\partial h}{\partial T} \right)_p$$

Ratio of specific heat capacities

$$\gamma \equiv \frac{c_p}{c_v}$$

Coefficient of volume expansion

$$\beta \equiv \frac{1}{v} \left(\frac{\partial v}{\partial T} \right)_p$$

Coefficient of compressibility

$$\kappa \equiv -\frac{1}{v} \left(\frac{\partial v}{\partial p} \right)_T$$

For a simple compressible substance, in the absence of capillarity, electric and magnetic fields

$$Tds = du + pdv = dh - vdp$$

IDEAL GAS RELATIONSHIPS

Equation of state	$\begin{cases} pV = n\bar{R}T \\ pV = mRT \\ pv = RT \\ p = \rho RT \end{cases}$
Relationship between c_p , c_v and R	$c_p - c_v = R$
Speed of sound	$a = \sqrt{\gamma RT}$

PERFECT GAS RELATIONSHIPS

Change in specific internal energy	$u_2 - u_1 = c_v(T_2 - T_1)$
Change in specific enthalpy	$h_2 - h_1 = c_p(T_2 - T_1)$
Change in specific entropy	$s_2 - s_1 = \begin{cases} c_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{v_2}{v_1}\right) \\ c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{p_2}{p_1}\right) \\ c_v \ln\left(\frac{p_2}{p_1}\right) + c_p \ln\left(\frac{v_2}{v_1}\right) \end{cases}$
For <i>Isentropic</i> changes	$pv^\gamma = \text{const.}$ $Tv^{\gamma-1} = \text{const.}$ $T/p^{(\gamma-1)/\gamma} = \text{const.}$

MIXTURES OF PERFECT GASES

For a mixture of N perfect gases where, for component $-i$, m_i = mass, p_i = partial pressure, $h_i = h_i(T)$ = partial specific enthalpy, $s_i = s_i(T, p_i)$ = partial specific entropy, n_i = number of mols and the overbar signifies a partial molar quantity:

Pressure of the mixture	$p_{mixture} = \sum_{i=1}^{i=N} p_i$
Enthalpy of the mixture	$H_{mixture} = \sum_{i=1}^{i=N} m_i h_i = \sum_{i=1}^{i=N} n_i \bar{h}_i$
Entropy of the mixture	$S_{mixture} = \sum_{i=1}^{i=N} m_i s_i = \sum_{i=1}^{i=N} n_i \bar{s}_i$

NON-DIMENSIONAL GROUPS

Reynolds Number $Re = \frac{\rho V d}{\mu} = \frac{V d}{\nu}$

Mach Number $M = \frac{V}{a}$

Froude Number $Fr = \frac{V}{\sqrt{gz}}$

Prandtl Number $Pr = \frac{\mu c_p}{\lambda} = \frac{\nu}{\alpha}$

Drag Coefficient $C_D = \frac{D}{\frac{1}{2} \rho V^2 A}$

Lift Coefficient $C_L = \frac{L}{\frac{1}{2} \rho V^2 A}$

Skin Friction Coefficient $c_f = \frac{\tau_w}{\frac{1}{2} \rho V^2}$

Friction Factor $f = 4c_f$

Discharge Coefficient $C_d = \frac{\dot{m}_{actual}}{\dot{m}_{ideal}}$

Nusselt Number $Nu = \frac{hd}{\lambda}$

Grashof Number $Gr = \frac{gd^3 \beta \Delta T}{\nu^2}$

Stanton Number $St = \frac{Nu}{Re Pr} = \frac{h}{\rho V c_p}$

HEAT TRANSFER

Conduction, Convection and Radiation

Rate of heat transfer \dot{Q} by *convection* from a body of surface area A

$$\dot{Q} = hA(T_{body} - T_{surroundings})$$

Rate of heat transfer \dot{Q} by *conduction* along a straight bar of cross-sectional area A

$$\dot{Q} = -\lambda A \frac{dT}{dx}$$

Rate of heat transfer \dot{Q} by *conduction* radially in a straight circular bar of length L

$$\dot{Q} = -\lambda 2\pi r L \frac{dT}{dr}$$

Rate of heat transfer \dot{Q} by *radiation*¹ from a grey body of surface area A and emissivity ε

$$\dot{Q} = \varepsilon \dot{Q}_{black} = \varepsilon \sigma A T^4$$

where $\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$ is the Stefan-Boltzmann constant.

Logarithmic-Mean Temperature Difference (LMTD)

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$$

Convective heat transfer for fully developed flow in circular pipes of diameter d

Overall heat transfer for laminar flow with constant wall temperature

$$Nu_d = 3.66 \qquad Re_d < 2300 \qquad 0.1 < Pr$$

Overall heat transfer for turbulent flow with constant wall temperature

$$Nu_d = 0.023 Re_d^{0.8} Pr^{0.4} \qquad 2300 < Re_d < 10^7 \qquad 0.5 < Pr < 120$$

Heat transfer due to natural convection from a vertical isothermal plate of height L

Overall heat transfer

$$Nu_L = 0.52 (GrPr)^{0.25} \qquad Pr \approx 1$$

Reynolds Analogy

$$St = \frac{c_f}{2}$$

¹ Note that the net rate of heat transfer will be less due to incident radiation

EQUATIONS FOR SYSTEMS

Definition of a system

A system is a fixed quantity of matter.

Conservation of mass applied to a system

The mass of a system is constant, i.e.

$$m = \text{const.}$$

1st Law of Thermodynamics applied to a system

When heat transfer to, and work done by, a system are defined as positive and the system is undergoing a cyclic process

$$\oint dQ = \oint dW$$

When heat transfer to, and work done by, a system of mass m undergoing a process between state 1 and state 2 are defined as positive and in the absence of capillarity, electric and magnetic fields

$$Q - W = E_2 - E_1 = (U_2 + \frac{1}{2}mV_2^2 + mgz_2) - (U_1 + \frac{1}{2}mV_1^2 + mgz_1)$$

2nd Law of Thermodynamics applied to a system

When heat transfer to a system undergoing a cyclic process is defined as positive, the Clausius inequality is

$$\oint \frac{dQ}{T} \leq 0$$

When heat transfer to a system of mass m undergoing a process is defined as positive

$$m ds = \frac{dQ}{T} + m ds_{\text{irrev}} \quad \text{where} \quad ds_{\text{irrev}} \geq 0$$

where ds_{irrev} is the entropy created per unit mass by irreversibilities.

$p dv$ work for a system

When the surface of a system undergoes displacement between state 1 and state 2 and the pressure causing the displacement is known over the entire surface that is displaced, the displacement work done by the system during this process is

$$W = \int_1^2 p dV$$

EQUATIONS FOR CONTROL VOLUMES

Definition of a control volume

A control volume is that region of space that is enclosed by a rigid control surface.

The requirements for steady flow within a control volume

For steady-flow, conditions within the control volume are not, on average, changing so that the mass, momentum, energy and entropy within the control volume remain constant.

Conservation of mass applied to a control volume - the *Continuity Equation*

In general, this may be written in vector form as

$$\frac{d}{dt} \iiint_{cv} \rho dV + \iint_{cs} \rho \underline{V} \cdot \underline{dA} = 0$$

where \underline{dA} is positive *out* of the control volume. It may also be written as

$$\frac{dm_{cv}}{dt} + \sum \dot{m}_{out} - \sum \dot{m}_{in} = 0$$

For *steady flow*, the above becomes

$$\sum \dot{m}_{out} = \sum \dot{m}_{in}$$

Momentum equations applied to a control volume, including the *Steady Flow Momentum Equation (SFME)*

In general, this may be written in vector form as

$$\frac{d}{dt} \iiint_{cv} \rho \underline{V} dV + \iint_{cs} \rho \underline{V} \underline{V} \cdot \underline{dA} = \underline{F} - \iint_{cs} p \underline{dA}$$

where \underline{dA} is positive *out* of the control volume and \underline{F} is the sum of all the non-pressure forces on the flow.

For *steady flow*, the above becomes the *Steady Flow Momentum Equation (SFME)*

$$\iint_{cs} \rho \underline{V} \underline{V} \cdot \underline{dA} = \underline{F} - \iint_{cs} p \underline{dA}$$

and in x and y coordinates, the *SFME* is

$$\sum \dot{m}_{out} V_{x,out} - \sum \dot{m}_{in} V_{x,in} = \sum F_x - \left(\sum pA \right)_x$$

$$\sum \dot{m}_{out} V_{y,out} - \sum \dot{m}_{in} V_{y,in} = \sum F_y - \left(\sum pA \right)_y$$

where care is needed with respect to the sign of the V_x , V_y and A terms.

1st Law of Thermodynamics applied to a control volume, including the *Steady Flow Energy Equation (SFEE)*

In the absence of capillarity, electric and magnetic fields, the 1st Law becomes

$$\frac{dE_{cv}}{dt} + \sum \dot{m}_{out} \left(h_{out} + \frac{1}{2} V_{out}^2 + gz_{out} \right) - \sum \dot{m}_{in} \left(h_{in} + \frac{1}{2} V_{in}^2 + gz_{in} \right) = \dot{Q} - \dot{W}_x$$

where E_{cv} is the total energy within the control volume, \dot{Q} is the rate of heat transfer to the control volume and \dot{W}_x is the rate of shaft work transferred from the control volume.

For *steady flow*, the above becomes the *Steady Flow Energy Equation (SFEE)*

$$\sum \dot{m}_{out} \left(h_{out} + \frac{1}{2} V_{out}^2 + gz_{out} \right) - \sum \dot{m}_{in} \left(h_{in} + \frac{1}{2} V_{in}^2 + gz_{in} \right) = \dot{Q} - \dot{W}_x$$

2nd Law of Thermodynamics applied to a control volume

When heat transfer to a control volume is defined as positive

$$\frac{dS_{cv}}{dt} + \sum \dot{m}_{out} s_{out} - \sum \dot{m}_{in} s_{in} = \int_A \frac{d\dot{Q}}{T} + \dot{S}_{irrev} \quad \text{where} \quad \dot{S}_{irrev} \geq 0$$

where $d\dot{Q}$ is the rate of heat transfer to an area dA of the control surface at temperature T and the integration is over the whole area A of the control surface, S_{cv} is the total entropy within the control volume and \dot{S}_{irrev} is the rate of entropy creation within the control volume due to irreversibilities.

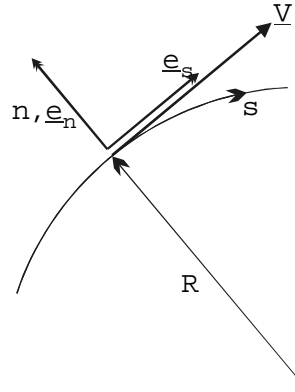
EQUATIONS FOR STREAMLINES

Bernoulli's Equation for incompressible inviscid steady flow along a streamline

$$p + \frac{1}{2}\rho V^2 + \rho gz = \text{const.}$$

The pressure gradient normal to a streamline with a radius of curvature R

$$\frac{dp}{dn} = \frac{\rho V^2}{R}$$



INCOMPRESSIBLE VISCOUS PIPE FLOW

The pressure drop along a pipe of constant diameter d and length L , with viscous flow

$$\Delta p = 4c_f \frac{L}{d} \frac{1}{2} \rho V^2 = f \frac{L}{d} \frac{1}{2} \rho V^2$$

EQUATIONS OF MOTION IN DIFFERENTIAL FORM FOR VISCOUS STEADY FLOW OF A FLUID

Mass conservation (continuity)

Intrinsic coordinates $\left(e_s \frac{\partial}{\partial s} + e_n \frac{\partial}{\partial n} \right) \cdot (\rho V e_s) = 0$

Vector Notation $\nabla \cdot (\rho \underline{V}) = 0$

Momentum

Intrinsic coordinates $\rho \left(V \frac{\partial V}{\partial s} e_s - \frac{V^2}{R} e_n \right) = -\frac{\partial p}{\partial s} e_s - \frac{\partial p}{\partial n} e_n + \rho \underline{g} + \underline{viscous}$

Vector Notation $\rho \underline{V} \cdot \nabla \underline{V} = -\nabla p + \rho \underline{g} + \underline{viscous}$

THERMODYNAMIC EFFICIENCIES

Efficiency of a cycle

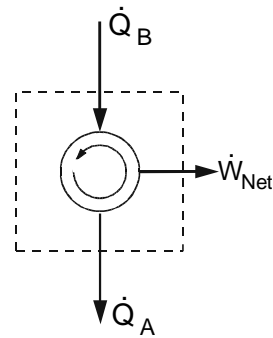
$$\eta_{cycle} \equiv \frac{\dot{W}_{net}}{\dot{Q}_B}$$

but

$$\dot{W}_{net} = \dot{Q}_B - \dot{Q}_A$$

so

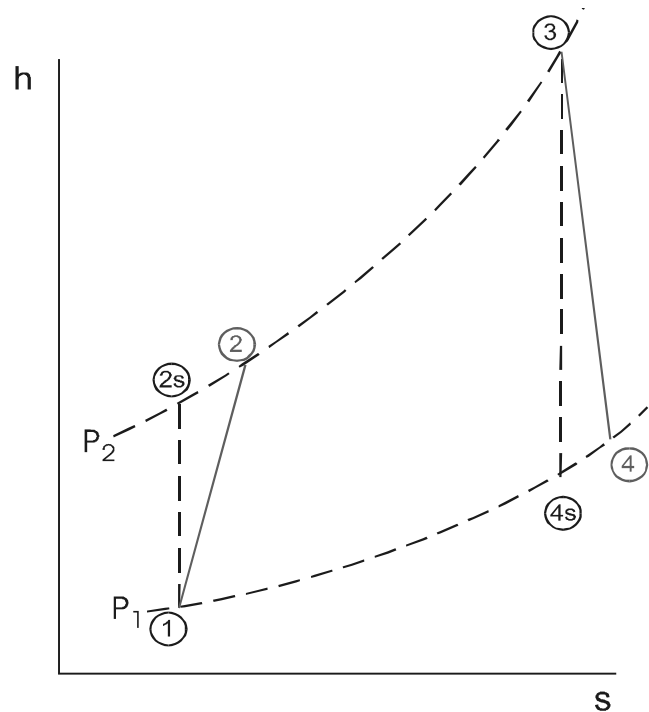
$$\eta_{cycle} = 1 - \frac{\dot{Q}_A}{\dot{Q}_B}$$



Isentropic efficiencies of compressors and turbines

$$\eta_c \equiv \frac{\text{Ideal Work Input}}{\text{Actual Work Input}} = \frac{h_{2s} - h_1}{h_2 - h_1}$$

$$\eta_t \equiv \frac{\text{Actual Work Output}}{\text{Ideal Work Output}} = \frac{h_3 - h_4}{h_3 - h_{4s}}$$



COMBUSTION

The SFEE applied to stoichiometric combustion at constant T and p

When heat transfer to a control volume is defined as positive and in the absence of shaft work, changes in KE and PE, capillarity, electric and magnetic fields, the rate of heat transfer and the calorific value (CV) are related by

$$\dot{Q} = \dot{m}_{fuel}(-CV) = \dot{m}_{fuel}\Delta\bar{h}$$

where

$$\dot{m}_{fuel} = M\dot{n}_{fuel}$$

Calorific values of common fuels (Enthalpies of Reaction)

In the following table, the calorific value is equal and opposite to the enthalpy of reaction when the reactants and products are at 25°C and 1.01324 bar. In the evaluation of the lower calorific value and lower enthalpy of reaction, the steam is assumed to be dry saturated.

Stoichiometric Equation	Molar Mass M of Fuel $\frac{\text{kg}}{\text{kmol}}$	Phase	Calorific Value MJ/kg	
			Higher: H_2O to water	Lower: H_2O to steam
$C + \frac{1}{2}O_2 \rightarrow CO$	12	solid	9.190	
$C + O_2 \rightarrow CO_2$	12	solid	32.760	
$CO + \frac{1}{2}O_2 \rightarrow CO_2$	28	gas	10.100	
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	2 [†]	gas	142.000	120.000
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	16	gas	55.500	50.010
$C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O$	30	gas	51.870	47.470
$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$	44	gas	50.360	46.360
$C_4H_{10} + 6.5O_2 \rightarrow 4CO_2 + 5H_2O$	58	gas	49.520	45.730
$C_8H_{18} + 12.5O_2 \rightarrow 8CO_2 + 9H_2O$	114	gas	48.270	44.800
$C_8H_{18} + 12.5O_2 \rightarrow 8CO_2 + 9H_2O$	114	liquid	47.900	44.430

[†] A more exact value is 2.016

PROPERTIES OF PERFECT GASES

Values of M , R , c_p , c_v and γ

At normal atmospheric conditions, and over a limited range of temperature and pressure, the gases listed below may be assumed to behave as perfect gases. That is, they may be assumed to have the equation of state $pv = RT$, and to have constant specific heat capacities.

Gas	Molar mass M kg/kmol	Gas constant R kJ/kg K	c_p kJ/kg K	c_v kJ/kg K	$\gamma \equiv \frac{c_p}{c_v}$
Air [#]	29.0	0.287	1.005	0.718	1.40
Atmospheric nitrogen [†]	28.15	0.295	1.033	0.738	1.40
N ₂	28	0.297	1.04	0.74	1.40
O ₂	32	0.260	0.92	0.66	1.40
A	40	0.208	0.52	0.31	1.67
H ₂	2 [*]	4.120	14.20	10.08	1.41
He	4	2.080	5.19	3.11	1.67
CO	28	0.297	1.04	0.74	1.40
CO ₂	44	0.189	0.82	0.63	1.31
SO ₂	64	0.130	0.61	0.48	1.26
CH ₄	16	0.520	2.23	1.71	1.31
C ₂ H ₆	30	0.277	1.75	1.47	1.19
C ₃ H ₆	42	0.198	1.52	1.32	1.15

Real gases are not perfect gases, and the rounded values for R , c_p , c_v and c_p/c_v listed above do not exactly satisfy the relationships between these quantities that would be obtained for perfect gases.

Molar (universal) gas constant

$$\bar{R} = MR = 8.3143 \text{ kJ/kmol K}$$

Molar volume of a perfect gas

1 kmol of any perfect gas occupies a volume of approximately 22.4 m³ at s.t.p. (0 °C and 1 bar) and contains 6.022×10^{26} particles.

[#] Air contains 21.0% O₂ and 79.0% atmospheric nitrogen by volume (*Volumetric and Molar Analyses*); 23.2% O₂ and 76.8% atmospheric nitrogen by weight (*Gravimetric Analysis*).

[†] Air contains 0.93 % of argon (A) and traces of other gases; these and the nitrogen together are called *atmospheric nitrogen*.

^{*} A more exact value is 2.016.

MOLAR ENTHALPIES OF COMMON GASES AT LOW PRESSURES

At low pressures, and over the temperature range quoted, the gases listed in this Table behave as semi-perfect gases. That is, while having the molar equation of state $p\nu = RT$, their specific heat capacities c_p and c_v are not constant but are functions only of temperature.

Gas	Air	N ₂	O ₂	H ₂	CO	CO ₂	H ₂ O	Gas
Molar Mass kg/kmol	29	28	32	2 [†]	28	44	18	Molar Mass kg/kmol
Temperature K	Molar enthalpy MJ/kmol							Temperature K
200	5.79	5.81	5.79	5.69	5.81	5.96	6.62	200
298.15=25°C	8.64	8.67	8.66	8.46	8.67	9.37	9.90	25°C=298.15
300	8.70	8.72	8.71	8.52	8.72	9.44	9.96	300
400	11.62	11.64	11.68	11.42	11.64	13.37	13.35	400
500	14.57	14.58	14.74	14.34	14.60	17.67	16.82	500
600	17.59	17.56	17.90	17.27	17.61	22.27	20.39	600
700	20.66	20.61	21.16	20.21	20.69	27.12	24.09	700
800	23.81	23.72	24.50	23.16	23.85	32.18	27.90	800
900	27.03	26.89	27.90	26.13	27.07	37.41	31.83	900
1000	30.30	30.14	31.37	29.14	30.36	42.78	35.90	1000
1100	33.64	33.44	34.88	32.18	33.71	48.27	40.09	1100
1200	37.02	36.79	38.43	35.26	37.11	53.87	44.41	1200
1300	40.44	40.19	42.01	38.38	40.54	59.55	48.84	1300
1400	43.90	43.62	45.63	41.54	44.02	65.31	53.39	1400
1500	47.39	47.09	49.27	44.75	47.53	71.13	58.05	1500
1600	50.92	50.59	52.94	48.00	51.07	77.01	62.81	1600
1700	54.47	54.12	56.63	51.29	54.63	82.94	67.65	1700
1800	58.04	57.67	60.35	54.62	58.21	88.92	72.58	1800
1900	61.63	61.25	64.09	58.00	61.81	94.93	77.59	1900
2000	65.24	64.84	67.86	61.40	65.42	100.97	82.67	2000
2100	68.87	68.44	71.65	64.84	69.06	107.05	87.81	2100
2200	72.52	72.06	75.46	68.31	72.70	113.15	93.01	2200
2300	76.18	75.70	79.29	71.82	76.36	119.28	98.27	2300
2400	79.86	79.35	83.14	75.35	80.03	125.43	103.58	2400
2500	83.55	83.01	87.02	78.90	83.71	131.61	108.94	2500
2600	87.25	86.68	90.92	82.48	87.40	137.80	114.34	2600
2700	90.96	90.36	94.83	86.09	91.10	144.02	119.78	2700
2800	94.69	94.05	98.77	89.72	94.80	150.25	125.26	2800
2900	98.42	97.74	102.72	93.37	98.51	156.50	130.77	2900
3000	102.16	101.44	106.70	97.04	102.23	162.76	136.31	3000

Notes:

- (1) The molar enthalpies listed are those in the ideal gas state at zero pressure, but the values given are also valid at and around atmospheric pressure.
- (2) In this table, the arbitrary datum state for zero enthalpy is that of the substance in the ideal gas state at zero pressure and zero absolute temperature.
- (3) The values for atmospheric nitrogen, N₂, may be taken to be the same as those for N₂.

[†] A more exact value is 2.016

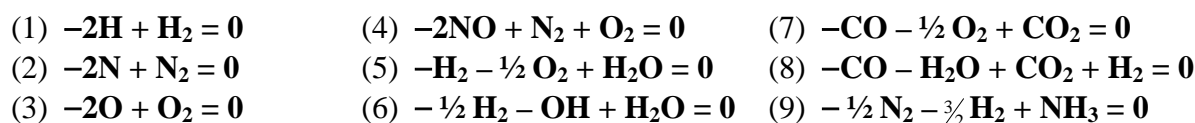
THERMOCHEMICAL DATA FOR EQUILIBRIUM REACTIONS

The tables of equilibrium constants and standard enthalpy change on the next page relate to the reactions listed below

Stoichiometric equations

$$\sum_i \nu_i A_i = 0$$

where ν_i is the stoichiometric coefficient of the substance whose chemical symbol is A_i .



Equilibrium constants

The equilibrium constant K_p is given by

$$\ln(K_p) = \sum_i \nu_i \ln p_i^*$$

where $p_i^* \equiv p_i' / p_0$

p_i' \equiv partial pressure of species A_i in **bars**

$p_0 \equiv$ standard pressure \equiv **1 bar**

Thus p_i^* is numerically equal to p_i' but is dimensionless.

Standard free enthalpy of reaction

At a given temperature, the standard free enthalpy of reaction (or the *standard Gibbs function change*) ΔG_T^0 may be calculated from the listed value of $\ln(K_p)$ by the following equation:

$$\begin{aligned} \Delta G_T^0 &= -\bar{R}T \ln K_p \\ &= -8.3145 T \ln(K_p) \quad \text{kJ} \end{aligned}$$

Standard enthalpy of reaction

The Standard enthalpy of reaction is given by

$$\Delta H_T^0 = \sum_i \nu_i [\tilde{h}_i]_T^0 = \sum_i \nu_i ([\Delta H_f]_T^0)_i$$

where

$$[\tilde{h}_i]_T^0 = ([\Delta H_f]_{298}^0)_i + ([\bar{h}]_T^0 - [\bar{h}]_{298}^0)_i$$

where $([\Delta H_f]_T^0)_i$ is the *standard enthalpy of formation* of species i at temperature T and a pressure $p_0 = 1$ bar.

Equilibrium constants & standard enthalpies of reaction

Reaction Number	1	2	3	4	5	6	7	8	9
$\sum_i \nu_i =$	-1	-1	-1	0	-1/2	-1/2	-1/2	0	-1
Temperature K	Equilibrium Constant $\ln(K_p)$								
200	250.149	554.472	285.471	105.592	139.972	161.789	159.692	19.719	15.433
298.15	163.986	367.479	186.975	69.865	92.207	106.228	103.762	11.554	6.593
400	119.150	270.329	135.715	51.311	67.321	77.284	74.669	7.348	1.778
600	75.217	175.356	85.523	33.203	42.897	48.905	46.245	3.348	-3.191
800	53.126	127.753	60.319	24.145	30.592	34.634	32.036	1.444	-5.822
1000	39.803	99.127	45.150	18.706	23.162	26.033	23.528	0.366	-7.457
1200	30.874	80.011	35.005	15.082	18.182	20.281	17.871	-0.311	-8.570
1400	24.463	66.329	27.742	12.489	14.608	16.160	13.841	-0.767	-9.371
1600	19.632	56.055	22.285	10.546	11.921	13.065	10.829	-1.091	-9.972
1800	15.865	48.051	18.030	9.035	9.825	10.657	8.497	-1.329	-10.439
2000	12.835	41.645	14.622	7.824	8.145	8.727	6.634	-1.510	-10.810
2200	10.353	36.391	11.827	6.834	6.768	7.148	5.119	-1.649	-11.109
2400	8.276	32.011	9.497	6.010	5.619	5.831	3.859	-1.759	-11.358
2600	6.512	28.304	7.521	5.314	4.647	4.718	2.800	-1.847	-11.563
2800	5.002	25.117	5.286	4.720	3.811	3.763	1.893	-1.918	-11.738
3000	3.685	22.359	4.357	4.205	3.086	2.936	1.110	-1.976	-11.885
Temperature K	Standard Enthalpy of Reaction ΔH_T^0 MJ								
200	-434.7	-944.1	-496.9	-180.4	-240.9	-280.2	-282.1	-41.21	-43.71
298.15	-436.0	-945.3	-498.4	-180.6	-241.8	-281.3	-283.0	-41.17	-45.90
400	-437.3	-946.6	-499.8	-180.7	-242.8	-282.4	-283.5	-40.63	-48.04
600	-439.7	-948.9	-502.1	-180.7	-244.8	-284.1	-283.6	-38.88	-51.39
800	-442.1	-951.1	-503.9	-180.8	-246.5	-285.5	-283.3	-36.82	-53.66
1000	-444.5	-953.0	-505.4	-180.9	-247.9	-286.6	-282.6	-34.74	-55.07
1200	-446.7	-954.7	-506.7	-180.9	-249.0	-287.4	-281.8	-32.79	-55.83
1400	-448.7	-956.1	-507.8	-181.0	-249.9	-287.9	-280.9	-30.98	-56.07
1600	-450.6	-957.5	-508.9	-181.0	-250.6	-288.4	-279.9	-29.29	-55.99
1800	-452.3	-958.7	-509.8	-181.0	-251.2	-288.6	-278.9	-27.71	-55.66
2000	-453.8	-959.9	-510.6	-181.0	-251.7	-288.8	-277.9	-26.22	-55.19
2200	-455.2	-961.0	-511.4	-180.8	-252.1	-288.9	-276.8	-24.79	-54.61
2400	-456.4	-962.1	-512.0	-180.7	-252.4	-289.0	-275.8	-23.41	-53.92
2600	-457.6	-963.1	-512.5	-180.4	-252.7	-289.0	-274.8	-22.07	-53.12
2800	-458.6	-964.1	-513.0	-180.1	-253.0	-288.9	-273.7	-20.77	-52.22
3000	-459.6	-965.0	-513.4	-179.7	-253.3	-288.9	-272.7	-19.49	-51.20

Warning: These tables list *absolute* temperatures

DATA FOR STEAM

Source of data

The following tables have been produced using equations from the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use and the Supplementary Release: Saturation Properties of Ordinary Water Substance. These documents can be found on the International Association for the Properties of Water and Steam website <http://www.iapws.org>.

TRIPLE POINT DATA FOR STEAM

Temperature = 273.16 K (0.01°C)
Pressure = 0.00611 bar

Phase	Specific volume m ³ /kg	Specific enthalpy kJ/kg	Specific entropy kJ/kg K
Ice	0.0010905	-333.5	-1.221
Water	0.0010002	0.0062	0.0
Steam	206	2500.9	9.156

CRITICAL POINT DATA FOR STEAM

Temperature = 647.096 K (373.946°C)
Pressure = 220.64 bar
Density = 322 kg/m³

PROPERTIES OF SATURATED WATER & STEAM:

Temperatures from the triple point to the critical point

Temp. °C	Pressure bar	Specific volume m ³ /kg		Spec. int. energy kJ/kg		Specific enthalpy kJ/kg			Specific entropy kJ/kg K		Temp. °C
<i>T</i>	<i>p</i>	<i>v_f</i>	<i>v_g</i>	<i>u_f</i>	<i>u_g</i>	<i>h_f</i>	<i>h_{fg}</i>	<i>h_g</i>	<i>s_f</i>	<i>s_g</i>	<i>T</i>
0.01	0.00611	0.001000	206.005	0.0	2375.0	0.0	2500.9	2500.9	0.000	9.156	0.01
2	0.00706	0.001000	179.776	8.4	2377.6	8.4	2496.2	2504.6	0.031	9.103	2
4	0.00814	0.001000	157.135	16.8	2380.4	16.8	2491.4	2508.2	0.061	9.051	4
6	0.00935	0.001000	137.652	25.2	2383.1	25.2	2486.7	2511.9	0.091	8.999	6
8	0.01073	0.001000	120.846	33.6	2385.9	33.6	2481.9	2515.6	0.121	8.949	8
10	0.01228	0.001000	106.319	42.0	2388.6	42.0	2477.2	2519.2	0.151	8.900	10
12	0.01403	0.001001	93.732	50.4	2391.4	50.4	2472.5	2522.9	0.181	8.851	12
14	0.01599	0.001001	82.804	58.8	2394.1	58.8	2467.7	2526.5	0.210	8.804	14
16	0.01819	0.001001	73.295	67.2	2396.9	67.2	2463.0	2530.2	0.239	8.757	16
18	0.02065	0.001001	65.005	75.5	2399.6	75.5	2458.3	2533.8	0.268	8.711	18
20	0.02339	0.001002	57.762	83.9	2402.3	83.9	2453.5	2537.4	0.296	8.666	20
22	0.02645	0.001002	51.422	92.3	2405.0	92.3	2448.8	2541.1	0.325	8.622	22
24	0.02986	0.001003	45.861	100.6	2407.8	100.6	2444.1	2544.7	0.353	8.578	24
25	0.03170	0.001003	43.340	104.8	2409.1	104.8	2441.7	2546.5	0.367	8.557	25
26	0.03364	0.001003	40.975	109.0	2410.5	109.0	2439.3	2548.3	0.381	8.535	26
28	0.03783	0.001004	36.673	117.4	2413.2	117.4	2434.6	2551.9	0.409	8.493	28
30	0.04247	0.001004	32.879	125.7	2415.9	125.7	2429.8	2555.5	0.437	8.452	30
32	0.04760	0.001005	29.527	134.1	2418.6	134.1	2425.1	2559.2	0.464	8.411	32
34	0.05325	0.001006	26.560	142.4	2421.3	142.4	2420.3	2562.8	0.492	8.371	34
36	0.05948	0.001006	23.929	150.8	2424.0	150.8	2415.5	2566.3	0.519	8.332	36
38	0.06633	0.001007	21.593	159.2	2426.7	159.2	2410.8	2569.9	0.546	8.294	38
40	0.07385	0.001008	19.515	167.5	2429.4	167.5	2406.0	2573.5	0.572	8.256	40
42	0.08210	0.001009	17.663	175.9	2432.1	175.9	2401.2	2577.1	0.599	8.218	42
44	0.09113	0.001010	16.010	184.2	2434.7	184.2	2396.4	2580.6	0.625	8.181	44
46	0.10100	0.001010	14.534	192.6	2437.4	192.6	2391.6	2584.2	0.652	8.145	46
48	0.11178	0.001011	13.212	201.0	2440.1	201.0	2386.8	2587.8	0.678	8.110	48
50	0.12352	0.001012	12.026	209.3	2442.7	209.3	2382.0	2591.3	0.704	8.075	50
52	0.13632	0.001013	10.962	217.7	2445.4	217.7	2377.1	2594.8	0.730	8.040	52
54	0.15023	0.001014	10.006	226.0	2448.0	226.1	2372.3	2598.3	0.755	8.007	54
56	0.16534	0.001015	9.145	234.4	2450.7	234.4	2367.4	2601.8	0.781	7.973	56
58	0.18172	0.001016	8.368	242.8	2453.3	242.8	2362.5	2605.3	0.806	7.940	58
60	0.19947	0.001017	7.667	251.1	2455.9	251.2	2357.7	2608.8	0.831	7.908	60
62	0.21868	0.001018	7.033	259.5	2458.5	259.5	2352.8	2612.3	0.856	7.876	62
64	0.23944	0.001019	6.460	267.9	2461.1	267.9	2347.9	2615.8	0.881	7.845	64
66	0.26184	0.001020	5.940	276.3	2463.7	276.3	2342.9	2619.2	0.906	7.814	66
68	0.28600	0.001022	5.468	284.6	2466.3	284.7	2338.0	2622.7	0.931	7.784	68
70	0.31202	0.001023	5.040	293.0	2468.8	293.1	2333.0	2626.1	0.955	7.754	70
72	0.34002	0.001024	4.650	301.4	2471.4	301.4	2328.1	2629.5	0.979	7.725	72
74	0.37010	0.001025	4.295	309.8	2474.0	309.8	2323.1	2632.9	1.004	7.696	74
76	0.40240	0.001026	3.971	318.2	2476.5	318.2	2318.1	2636.3	1.028	7.667	76
78	0.43704	0.001028	3.675	326.6	2479.0	326.6	2313.1	2639.7	1.052	7.639	78
80	0.47416	0.001029	3.405	335.0	2481.5	335.0	2308.0	2643.0	1.076	7.611	80
82	0.51388	0.001030	3.158	343.3	2484.1	343.4	2303.0	2646.4	1.099	7.584	82
84	0.55636	0.001032	2.932	351.7	2486.5	351.8	2297.9	2649.7	1.123	7.557	84
86	0.60174	0.001033	2.725	360.1	2489.0	360.2	2292.8	2653.0	1.146	7.530	86
88	0.65018	0.001035	2.534	368.6	2491.5	368.6	2287.6	2656.3	1.170	7.504	88
90	0.70183	0.001036	2.359	377.0	2494.0	377.0	2282.5	2659.5	1.193	7.478	90
92	0.75685	0.001037	2.198	385.4	2496.4	385.4	2277.3	2662.8	1.216	7.453	92
94	0.81542	0.001039	2.050	393.8	2498.8	393.9	2272.1	2666.0	1.239	7.428	94
96	0.87771	0.001040	1.914	402.2	2501.2	402.3	2266.9	2669.2	1.262	7.403	96
98	0.94390	0.001042	1.788	410.6	2503.6	410.7	2261.7	2672.4	1.285	7.378	98
100	1.01418	0.001043	1.672	419.1	2506.0	419.2	2256.4	2675.6	1.307	7.354	100
<i>T</i>	<i>p</i>	<i>v_f</i>	<i>v_g</i>	<i>u_f</i>	<i>u_g</i>	<i>h_f</i>	<i>h_{fg}</i>	<i>h_g</i>	<i>s_f</i>	<i>s_g</i>	<i>T</i>

**Properties of Saturated Water & Steam continued:
Temperatures from the triple point to the critical point**

Temp. °C	Pressure bar	Specific volume m ³ /kg		Spec. int. energy kJ/kg		Specific enthalpy kJ/kg			Specific entropy kJ/kg K		Temp. °C
<i>T</i>	<i>p</i>	<i>v_f</i>	<i>v_g</i>	<i>u_f</i>	<i>u_g</i>	<i>h_f</i>	<i>h_{fg}</i>	<i>h_g</i>	<i>s_f</i>	<i>s_g</i>	<i>T</i>
100	1.014	0.001043	1.67196	419.1	2506.0	419.1	2256.4	2675.6	1.307	7.354	100
105	1.209	0.001047	1.41856	440.1	2511.9	440.3	2243.1	2683.4	1.363	7.295	105
110	1.434	0.001052	1.20945	461.3	2517.7	461.4	2229.6	2691.1	1.419	7.238	110
115	1.692	0.001056	1.03598	482.4	2523.3	482.6	2216.0	2698.6	1.474	7.183	115
120	1.987	0.001060	0.89133	503.6	2528.8	503.8	2202.1	2705.9	1.528	7.129	120
125	2.322	0.001065	0.77012	524.8	2534.3	525.1	2188.0	2713.1	1.582	7.077	125
130	2.703	0.001070	0.66808	546.1	2539.5	546.4	2173.7	2720.1	1.635	7.026	130
135	3.132	0.001075	0.58179	567.4	2544.6	567.7	2159.1	2726.9	1.687	6.977	135
140	3.615	0.001080	0.50850	588.8	2549.6	589.2	2144.3	2733.4	1.739	6.929	140
145	4.157	0.001085	0.44600	610.2	2554.4	610.6	2129.2	2739.8	1.791	6.883	145
150	4.762	0.001091	0.39248	631.7	2559.0	632.2	2113.7	2745.9	1.842	6.837	150
155	5.435	0.001096	0.34648	653.2	2563.5	653.8	2098.0	2751.8	1.892	6.793	155
160	6.182	0.001102	0.30680	674.8	2567.8	675.5	2082.0	2757.4	1.943	6.749	160
165	7.009	0.001108	0.27244	696.5	2571.8	697.2	2065.6	2762.8	1.992	6.707	165
170	7.922	0.001114	0.24260	718.2	2575.7	719.1	2048.8	2767.9	2.042	6.665	170
175	8.926	0.001121	0.21659	740.0	2579.4	741.0	2031.7	2772.7	2.091	6.624	175
180	10.028	0.001127	0.19384	761.9	2582.8	763.1	2014.2	2777.2	2.139	6.584	180
185	11.235	0.001134	0.17390	783.9	2586.0	785.2	1996.2	2781.4	2.188	6.545	185
190	12.552	0.001141	0.15636	806.0	2589.0	807.4	1977.8	2785.3	2.235	6.506	190
195	13.988	0.001149	0.14089	828.2	2591.7	829.8	1959.0	2788.8	2.283	6.468	195
200	15.549	0.001157	0.12721	850.5	2594.2	852.3	1939.7	2792.0	2.331	6.430	200
205	17.243	0.001164	0.11508	872.9	2596.4	874.9	1919.9	2794.8	2.378	6.393	205
210	19.077	0.001173	0.10429	895.4	2598.3	897.6	1899.6	2797.3	2.424	6.356	210
215	21.059	0.001181	0.09468	918.0	2599.9	920.5	1878.8	2799.3	2.471	6.320	215
220	23.196	0.001190	0.08609	940.8	2601.2	943.6	1857.4	2800.9	2.518	6.284	220
225	25.497	0.001199	0.07841	963.7	2602.2	966.8	1835.3	2802.2	2.564	6.248	225
230	27.971	0.001209	0.07151	986.8	2602.9	990.2	1812.7	2802.9	2.610	6.213	230
235	30.626	0.001219	0.06530	1010.0	2603.2	1013.8	1789.4	2803.2	2.656	6.178	235
240	33.470	0.001229	0.05971	1033.4	2603.1	1037.6	1765.4	2803.0	2.702	6.142	240
245	36.512	0.001240	0.05466	1057.0	2602.7	1061.5	1740.7	2802.2	2.748	6.107	245
250	39.762	0.001252	0.05009	1080.8	2601.8	1085.8	1715.2	2800.9	2.793	6.072	250
255	43.229	0.001263	0.04594	1104.8	2600.5	1110.2	1688.9	2799.1	2.839	6.037	255
260	46.923	0.001276	0.04218	1129.0	2598.7	1134.9	1661.7	2796.6	2.885	6.002	260
265	50.853	0.001289	0.03875	1153.4	2596.5	1159.9	1633.6	2793.5	2.930	5.966	265
270	55.030	0.001303	0.03562	1178.1	2593.7	1185.2	1604.5	2789.7	2.976	5.930	270
275	59.464	0.001317	0.03277	1203.0	2590.3	1210.9	1574.3	2785.2	3.022	5.894	275
280	64.166	0.001333	0.03015	1228.3	2586.4	1236.8	1543.0	2779.9	3.068	5.858	280
285	69.146	0.001349	0.02776	1253.9	2581.8	1263.2	1510.5	2773.7	3.114	5.821	285
290	74.418	0.001366	0.02555	1279.8	2576.5	1290.0	1476.7	2766.7	3.161	5.783	290
295	79.991	0.001384	0.02353	1306.1	2570.5	1317.2	1441.5	2758.7	3.208	5.745	295
300	85.879	0.001404	0.02166	1332.8	2563.6	1344.9	1404.7	2749.6	3.255	5.706	300
305	92.094	0.001425	0.01993	1360.1	2555.8	1373.2	1366.2	2739.4	3.302	5.666	305
310	98.650	0.001447	0.01833	1387.8	2547.1	1402.1	1325.8	2727.9	3.351	5.624	310
315	105.561	0.001472	0.01685	1416.2	2537.2	1431.7	1283.3	2715.0	3.399	5.582	315
320	112.843	0.001499	0.01547	1445.2	2526.0	1462.1	1238.5	2700.6	3.449	5.537	320
325	120.510	0.001528	0.01418	1475.0	2513.4	1493.4	1190.9	2684.3	3.500	5.491	325
330	128.581	0.001560	0.01298	1505.7	2499.2	1525.8	1140.2	2666.0	3.552	5.442	330
335	137.073	0.001597	0.01185	1537.5	2483.0	1559.4	1086.0	2645.4	3.605	5.391	335
340	146.007	0.001638	0.01078	1570.7	2464.5	1594.6	1027.4	2621.9	3.660	5.336	340
345	155.406	0.001685	0.00977	1605.4	2443.2	1631.6	963.4	2595.1	3.718	5.276	345
350	165.293	0.001741	0.00881	1642.3	2418.3	1671.1	892.7	2563.8	3.779	5.211	350
355	175.700	0.001808	0.00787	1682.1	2388.6	1713.9	812.9	2526.9	3.844	5.138	355
360	186.660	0.001895	0.00695	1726.2	2351.8	1761.5	720.0	2481.6	3.916	5.054	360
365	198.218	0.002015	0.00601	1777.2	2303.6	1817.2	605.5	2422.7	4.000	4.949	365
370	210.438	0.002217	0.00495	1844.5	2230.1	1891.2	443.1	2334.3	4.112	4.801	370
373.95	220.640	0.003106	0.00311	2018.1	2018.1	2086.6	0.0	2086.6	4.410	4.410	373.95
<i>T</i>	<i>p</i>	<i>v_f</i>	<i>v_g</i>	<i>u_f</i>	<i>u_g</i>	<i>h_f</i>	<i>h_{fg}</i>	<i>h_g</i>	<i>s_f</i>	<i>s_g</i>	<i>T</i>

PROPERTIES OF SATURATED WATER & STEAM:

Pressures from the triple point to the critical point

Pressure bar p	Temp. °C T	Specific volume m^3/kg		Spec. int. energy kJ/kg		Specific enthalpy kJ/kg			Specific entropy kJ/kg K		Pressure bar p
		v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_g	
0.00611	0.01	0.001000	206.00	0.0	2375.0	0.0	2500.9	2500.9	0.000	9.156	0.00611
0.02	17.50	0.001001	66.99	73.4	2398.9	73.4	2459.5	2532.9	0.261	8.723	0.02
0.04	28.96	0.001004	34.79	121.4	2414.5	121.4	2432.3	2553.7	0.422	8.473	0.04
0.06	36.16	0.001006	23.73	151.5	2424.2	151.5	2415.2	2566.6	0.521	8.329	0.06
0.08	41.51	0.001008	18.10	173.8	2431.4	173.8	2402.4	2576.2	0.592	8.227	0.08
0.10	45.81	0.001010	14.67	191.8	2437.2	191.8	2392.1	2583.9	0.649	8.149	0.10
0.12	49.42	0.001012	12.36	206.9	2442.0	206.9	2383.4	2590.3	0.696	8.085	0.12
0.14	52.55	0.001013	10.69	220.0	2446.1	220.0	2375.8	2595.8	0.737	8.031	0.14
0.16	55.31	0.001015	9.43	231.5	2449.8	231.6	2369.1	2600.6	0.772	7.985	0.16
0.18	57.80	0.001016	8.44	241.9	2453.0	241.9	2363.0	2605.0	0.804	7.944	0.18
0.20	60.06	0.001017	7.65	251.4	2456.0	251.4	2357.5	2608.9	0.832	7.907	0.20
0.22	62.13	0.001018	6.99	260.1	2458.7	260.1	2352.4	2612.5	0.858	7.874	0.22
0.24	64.05	0.001019	6.45	268.1	2461.2	268.1	2347.7	2615.9	0.882	7.844	0.24
0.26	65.84	0.001020	5.98	275.6	2463.5	275.6	2343.3	2619.0	0.904	7.817	0.26
0.28	67.52	0.001021	5.58	282.6	2465.7	282.6	2339.2	2621.8	0.925	7.791	0.28
0.30	69.09	0.001022	5.23	289.2	2467.7	289.3	2335.3	2624.5	0.944	7.767	0.30
0.32	70.58	0.001023	4.92	295.5	2469.6	295.5	2331.6	2627.1	0.962	7.745	0.32
0.34	72.00	0.001024	4.65	301.4	2471.4	301.4	2328.1	2629.5	0.979	7.725	0.34
0.36	73.34	0.001025	4.41	307.0	2473.1	307.1	2324.7	2631.8	0.996	7.705	0.36
0.38	74.63	0.001026	4.19	312.4	2474.8	312.5	2321.5	2634.0	1.011	7.687	0.38
0.40	75.86	0.001026	3.99	317.6	2476.3	317.6	2318.4	2636.1	1.026	7.669	0.40
0.42	77.03	0.001027	3.81	322.5	2477.8	322.6	2315.5	2638.0	1.040	7.652	0.42
0.44	78.16	0.001028	3.65	327.3	2479.2	327.3	2312.6	2639.9	1.054	7.637	0.44
0.46	79.25	0.001029	3.50	331.8	2480.6	331.9	2309.9	2641.8	1.067	7.621	0.46
0.48	80.30	0.001029	3.37	336.2	2481.9	336.3	2307.2	2643.5	1.079	7.607	0.48
0.50	81.32	0.001030	3.24	340.5	2483.2	340.5	2304.7	2645.2	1.091	7.593	0.50
0.52	82.30	0.001031	3.12	344.6	2484.4	344.6	2302.2	2646.8	1.103	7.580	0.52
0.54	83.25	0.001031	3.02	348.6	2485.6	348.6	2299.8	2648.4	1.114	7.567	0.54
0.56	84.17	0.001032	2.91	352.4	2486.8	352.5	2297.4	2649.9	1.125	7.555	0.56
0.58	85.06	0.001032	2.82	356.2	2487.9	356.3	2295.2	2651.4	1.135	7.543	0.58
0.60	85.93	0.001033	2.73	359.8	2488.9	359.9	2293.0	2652.9	1.145	7.531	0.60
0.62	86.77	0.001034	2.65	363.4	2490.0	363.4	2290.8	2654.2	1.155	7.520	0.62
0.64	87.59	0.001034	2.57	366.8	2491.0	366.9	2288.7	2655.6	1.165	7.509	0.64
0.66	88.39	0.001035	2.50	370.2	2492.0	370.3	2286.6	2656.9	1.174	7.499	0.66
0.68	89.17	0.001035	2.43	373.5	2492.9	373.5	2284.6	2658.2	1.183	7.489	0.68
0.70	89.93	0.001036	2.37	376.7	2493.9	376.7	2282.7	2659.4	1.192	7.479	0.70
0.72	90.67	0.001036	2.30	379.8	2494.8	379.9	2280.8	2660.6	1.201	7.470	0.72
0.74	91.40	0.001037	2.25	382.9	2495.7	382.9	2278.9	2661.8	1.209	7.460	0.74
0.76	92.11	0.001037	2.19	385.8	2496.5	385.9	2277.0	2663.0	1.217	7.451	0.76
0.78	92.81	0.001038	2.14	388.8	2497.4	388.8	2275.2	2664.1	1.225	7.443	0.78
0.80	93.49	0.001039	2.09	391.6	2498.2	391.7	2273.5	2665.2	1.233	7.434	0.80
0.82	94.15	0.001039	2.04	394.4	2499.0	394.5	2271.7	2666.3	1.241	7.426	0.82
0.84	94.80	0.001039	1.99	397.2	2499.8	397.3	2270.0	2667.3	1.248	7.418	0.84
0.86	95.44	0.001040	1.95	399.9	2500.6	400.0	2268.4	2668.3	1.255	7.410	0.86
0.88	96.07	0.001040	1.91	402.5	2501.3	402.6	2266.7	2669.3	1.263	7.402	0.88
0.90	96.69	0.001041	1.87	405.1	2502.1	405.2	2265.1	2670.3	1.270	7.394	0.90
0.92	97.29	0.001041	1.83	407.6	2502.8	407.7	2263.5	2671.3	1.277	7.387	0.92
0.94	97.89	0.001042	1.80	410.1	2503.5	410.2	2262.0	2672.2	1.283	7.380	0.94
0.96	98.47	0.001042	1.76	412.6	2504.2	412.7	2260.4	2673.1	1.290	7.373	0.96
0.98	99.04	0.001043	1.73	415.0	2504.9	415.1	2258.9	2674.1	1.296	7.366	0.98
1.00	99.61	0.001043	1.69	417.4	2505.5	417.5	2257.4	2674.9	1.303	7.359	1.00
p	T	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_g	p

Properties of Saturated Water & Steam continued:
Pressures from the triple point to the critical point

Pressure bar p	Temp. °C T	Specific volume m^3/kg v_f v_g		Spec. int. energy kJ/kg u_f u_g		Specific enthalpy kJ/kg h_f h_{fg} h_g			Specific entropy kJ/kg K s_f s_g		Pressure bar p
1.0	99.61	0.001043	1.6941	417.4	2505.5	417.5	2257.4	2674.9	1.303	7.359	1.0
1.5	111.35	0.001053	1.1594	467.0	2519.2	467.1	2226.0	2693.1	1.434	7.223	1.5
2.0	120.21	0.001061	0.8858	504.5	2529.1	504.7	2201.5	2706.2	1.530	7.127	2.0
2.5	127.41	0.001067	0.7187	535.1	2536.8	535.3	2181.1	2716.5	1.607	7.053	2.5
3.0	133.52	0.001073	0.6058	561.1	2543.1	561.4	2163.5	2724.9	1.672	6.992	3.0
3.5	138.86	0.001079	0.5242	583.9	2548.5	584.3	2147.7	2732.0	1.727	6.940	3.5
4.0	143.61	0.001084	0.4624	604.2	2553.1	604.7	2133.4	2738.1	1.776	6.896	4.0
4.5	147.90	0.001088	0.4139	622.7	2557.1	623.1	2120.2	2743.4	1.820	6.856	4.5
5.0	151.83	0.001093	0.3748	639.5	2560.7	640.1	2108.0	2748.1	1.860	6.821	5.0
5.5	155.46	0.001097	0.3426	655.2	2563.9	655.8	2096.6	2752.3	1.897	6.789	5.5
6.0	158.83	0.001101	0.3156	669.7	2566.8	670.4	2085.8	2756.1	1.931	6.759	6.0
6.5	161.98	0.001104	0.2926	683.4	2569.4	684.1	2075.5	2759.6	1.962	6.732	6.5
7.0	164.95	0.001108	0.2728	696.2	2571.8	697.0	2065.8	2762.8	1.992	6.707	7.0
7.5	167.75	0.001111	0.2555	708.4	2574.0	709.2	2056.4	2765.6	2.019	6.684	7.5
8.0	170.41	0.001115	0.2403	720.0	2576.0	720.9	2047.4	2768.3	2.046	6.662	8.0
8.5	172.94	0.001118	0.2269	731.0	2577.9	732.0	2038.8	2770.8	2.070	6.641	8.5
9.0	175.35	0.001121	0.2149	741.6	2579.6	742.6	2030.5	2773.0	2.094	6.621	9.0
9.5	177.66	0.001124	0.2041	751.7	2581.2	752.7	2022.4	2775.1	2.117	6.603	9.5
10.0	179.88	0.001127	0.1944	761.4	2582.7	762.5	2014.6	2777.1	2.138	6.585	10.0
10.5	182.01	0.001130	0.1855	770.8	2584.1	771.9	2007.0	2778.9	2.159	6.568	10.5
11.0	184.06	0.001133	0.1775	779.8	2585.5	781.0	1999.6	2780.6	2.178	6.552	11.0
11.5	186.04	0.001136	0.1701	788.5	2586.7	789.8	1992.4	2782.2	2.198	6.537	11.5
12.0	187.96	0.001138	0.1633	797.0	2587.8	798.3	1985.4	2783.7	2.216	6.522	12.0
12.5	189.81	0.001141	0.1570	805.2	2588.9	806.6	1978.6	2785.1	2.234	6.507	12.5
13.0	191.60	0.001144	0.1512	813.1	2589.9	814.6	1971.9	2786.5	2.251	6.494	13.0
13.5	193.35	0.001146	0.1458	820.8	2590.9	822.4	1965.3	2787.7	2.267	6.480	13.5
14.0	195.04	0.001149	0.1408	828.4	2591.8	830.0	1958.9	2788.8	2.284	6.467	14.0
14.5	196.68	0.001151	0.1361	835.7	2592.6	837.4	1952.6	2789.9	2.299	6.455	14.5
15.0	198.29	0.001154	0.1317	842.8	2593.4	844.6	1946.4	2791.0	2.314	6.443	15.0
15.5	199.85	0.001156	0.1276	849.8	2594.1	851.6	1940.3	2791.9	2.329	6.431	15.5
16.0	201.37	0.001159	0.1237	856.6	2594.8	858.5	1934.4	2792.8	2.343	6.420	16.0
16.5	202.86	0.001161	0.1201	863.3	2595.5	865.2	1928.5	2793.7	2.357	6.409	16.5
17.0	204.31	0.001163	0.1167	869.8	2596.1	871.7	1922.7	2794.5	2.371	6.398	17.0
17.5	205.72	0.001166	0.1134	876.1	2596.7	878.2	1917.0	2795.2	2.384	6.388	17.5
18.0	207.11	0.001168	0.1104	882.4	2597.2	884.5	1911.4	2795.9	2.397	6.377	18.0
18.5	208.47	0.001170	0.1075	888.5	2597.8	890.7	1905.9	2796.6	2.410	6.368	18.5
19.0	209.80	0.001172	0.1047	894.5	2598.2	896.7	1900.5	2797.2	2.423	6.358	19.0
19.5	211.10	0.001175	0.1021	900.4	2598.7	902.7	1895.1	2797.8	2.435	6.348	19.5
20.0	212.38	0.001177	0.0996	906.2	2599.1	908.5	1889.8	2798.3	2.447	6.339	20.0
20.5	213.63	0.001179	0.0972	911.8	2599.5	914.2	1884.6	2798.8	2.458	6.330	20.5
21.0	214.86	0.001181	0.0949	917.4	2599.9	919.9	1879.4	2799.3	2.470	6.321	21.0
21.5	216.06	0.001183	0.0928	922.9	2600.2	925.4	1874.3	2799.7	2.481	6.312	21.5
22.0	217.25	0.001185	0.0907	928.3	2600.6	930.9	1869.2	2800.1	2.492	6.304	22.0
22.5	218.41	0.001187	0.0887	933.6	2600.9	936.3	1864.2	2800.5	2.503	6.295	22.5
23.0	219.56	0.001189	0.0868	938.8	2601.1	941.5	1859.3	2800.8	2.513	6.287	23.0
23.5	220.68	0.001191	0.0850	943.9	2601.4	946.7	1854.4	2801.1	2.524	6.279	23.5
24.0	221.79	0.001193	0.0832	949.0	2601.6	951.9	1849.6	2801.4	2.534	6.271	24.0
24.5	222.88	0.001195	0.0816	954.0	2601.9	956.9	1844.8	2801.7	2.544	6.263	24.5
25.0	223.95	0.001197	0.0800	958.9	2602.1	961.9	1840.0	2801.9	2.554	6.256	25.0
25.5	225.01	0.001199	0.0784	963.8	2602.2	966.8	1835.3	2802.2	2.564	6.248	25.5
p	T	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_g	p

Properties of Saturated Water & Steam continued:
Pressures from the triple point to the critical point

Pressure bar	Temp. °C	Specific volume m ³ /kg		Spec. int. energy kJ/kg		Specific enthalpy kJ/kg			Specific entropy kJ/kg K		Pressure bar
p	T	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_g	p
26.0	226.05	0.001201	0.0769	968.6	2602.4	971.7	1830.7	2802.3	2.574	6.241	26.0
26.5	227.07	0.001203	0.0755	973.3	2602.5	976.5	1826.1	2802.5	2.583	6.234	26.5
27.0	228.08	0.001205	0.0741	977.9	2602.7	981.2	1821.5	2802.7	2.592	6.226	27.0
27.5	229.07	0.001207	0.0727	982.5	2602.8	985.9	1816.9	2802.8	2.601	6.219	27.5
28.0	230.06	0.001209	0.0714	987.1	2602.9	990.5	1812.4	2802.9	2.611	6.212	28.0
28.5	231.02	0.001211	0.0702	991.6	2603.0	995.0	1808.0	2803.0	2.619	6.206	28.5
29.0	231.98	0.001213	0.0690	996.0	2603.1	999.5	1803.6	2803.1	2.628	6.199	29.0
29.5	232.92	0.001215	0.0678	1000.4	2603.1	1004.0	1799.2	2803.1	2.637	6.192	29.5
30	233.85	0.001217	0.06667	1004.7	2603.2	1008.4	1794.8	2803.2	2.645	6.186	30
32	237.46	0.001224	0.06248	1021.5	2603.2	1025.4	1777.7	2803.1	2.679	6.160	32
34	240.90	0.001231	0.05876	1037.7	2603.1	1041.8	1761.0	2802.9	2.710	6.136	34
36	244.18	0.001238	0.05545	1053.1	2602.8	1057.6	1744.8	2802.4	2.740	6.113	36
38	247.33	0.001245	0.05247	1068.1	2602.3	1072.8	1728.9	2801.7	2.769	6.091	38
40	250.35	0.001252	0.04978	1082.5	2601.7	1087.5	1713.3	2800.8	2.797	6.070	40
42	253.26	0.001259	0.04733	1096.4	2601.0	1101.7	1698.1	2799.8	2.823	6.049	42
44	256.07	0.001266	0.04510	1109.9	2600.1	1115.5	1683.1	2798.6	2.849	6.029	44
46	258.78	0.001273	0.04306	1123.0	2599.2	1128.9	1668.4	2797.3	2.874	6.010	46
48	261.40	0.001280	0.04118	1135.8	2598.1	1141.9	1653.9	2795.8	2.898	5.992	48
50	263.94	0.001286	0.03945	1148.2	2597.0	1154.6	1639.6	2794.2	2.921	5.974	50
52	266.40	0.001293	0.03784	1160.3	2595.7	1167.0	1625.5	2792.5	2.943	5.956	52
54	268.79	0.001299	0.03635	1172.1	2594.4	1179.1	1611.6	2790.7	2.965	5.939	54
56	271.12	0.001306	0.03496	1183.6	2593.0	1190.9	1597.8	2788.8	2.986	5.922	56
58	273.38	0.001312	0.03366	1194.9	2591.5	1202.5	1584.2	2786.7	3.007	5.906	58
60	275.58	0.001319	0.03245	1206.0	2589.9	1213.9	1570.7	2784.6	3.027	5.890	60
62	277.73	0.001326	0.03131	1216.8	2588.3	1225.0	1557.4	2782.4	3.047	5.875	62
64	279.83	0.001332	0.03024	1227.4	2586.5	1235.9	1544.1	2780.1	3.067	5.859	64
66	281.87	0.001339	0.02923	1237.8	2584.8	1246.7	1531.0	2777.7	3.085	5.844	66
68	283.87	0.001345	0.02828	1248.1	2582.9	1257.2	1518.0	2775.2	3.104	5.829	68
70	285.83	0.001352	0.02738	1258.1	2581.0	1267.6	1505.0	2772.6	3.122	5.815	70
72	287.74	0.001358	0.02653	1268.0	2579.0	1277.8	1492.2	2770.0	3.140	5.800	72
74	289.61	0.001365	0.02572	1277.8	2577.0	1287.9	1479.4	2767.3	3.157	5.786	74
76	291.45	0.001371	0.02495	1287.4	2574.9	1297.8	1466.7	2764.5	3.174	5.772	76
78	293.25	0.001378	0.02422	1296.8	2572.7	1307.6	1454.0	2761.6	3.191	5.759	78
80	295.01	0.001384	0.02352	1306.1	2570.5	1317.2	1441.4	2758.7	3.208	5.745	80
82	296.74	0.001391	0.02286	1315.3	2568.2	1326.7	1428.9	2755.7	3.224	5.732	82
84	298.43	0.001398	0.02223	1324.4	2565.9	1336.2	1416.4	2752.6	3.240	5.718	84
86	300.10	0.001404	0.02162	1333.4	2563.5	1345.5	1404.0	2749.4	3.256	5.705	86
88	301.74	0.001411	0.02104	1342.2	2561.0	1354.7	1391.5	2746.2	3.271	5.692	88
90	303.35	0.001418	0.02049	1351.0	2558.5	1363.8	1379.2	2742.9	3.287	5.679	90
92	304.93	0.001425	0.01996	1359.7	2556.0	1372.8	1366.8	2739.6	3.302	5.666	92
94	306.48	0.001431	0.01945	1368.2	2553.3	1381.7	1354.5	2736.1	3.317	5.654	94
96	308.01	0.001438	0.01895	1376.7	2550.7	1390.5	1342.1	2732.6	3.331	5.641	96
98	309.52	0.001445	0.01848	1385.1	2548.0	1399.3	1329.8	2729.1	3.346	5.628	98
100	311.00	0.001452	0.01803	1393.4	2545.2	1407.9	1317.5	2725.5	3.360	5.616	100
105	314.60	0.001470	0.01696	1413.9	2538.0	1429.3	1286.8	2716.1	3.396	5.585	105
110	318.08	0.001488	0.01599	1433.9	2530.4	1450.3	1256.0	2706.3	3.430	5.554	110
115	321.43	0.001507	0.01509	1453.6	2522.5	1471.0	1225.1	2696.1	3.464	5.524	115
120	324.68	0.001526	0.01426	1473.0	2514.3	1491.3	1194.1	2685.4	3.496	5.494	120
125	327.81	0.001546	0.01350	1492.2	2505.6	1511.5	1162.8	2674.3	3.529	5.464	125
130	330.85	0.001566	0.01278	1511.1	2496.5	1531.4	1131.3	2662.7	3.561	5.434	130
135	333.80	0.001588	0.01211	1529.8	2487.0	1551.2	1099.3	2650.6	3.592	5.403	135
140	336.67	0.001610	0.01149	1548.4	2477.1	1571.0	1067.0	2637.9	3.623	5.373	140
145	339.45	0.001633	0.01090	1566.9	2466.7	1590.6	1034.1	2624.7	3.654	5.342	145
p	T	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_g	p

Properties of Saturated Water & Steam continued:
Pressures from the triple point to the critical point

Pressure bar	Temp. °C	Specific volume m ³ /kg		Spec. int. energy kJ/kg		Specific enthalpy kJ/kg			Specific entropy kJ/kg K		Pressure bar
p	T	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_g	p
150	342.16	0.001657	0.01034	1585.4	2455.7	1610.3	1000.5	2610.8	3.685	5.311	150
155	344.79	0.001683	0.00981	1603.9	2444.2	1630.0	966.2	2596.3	3.715	5.279	155
160	347.35	0.001710	0.00931	1622.5	2432.0	1649.9	931.1	2581.0	3.746	5.247	160
165	349.86	0.001739	0.00883	1641.2	2419.1	1669.9	894.9	2564.8	3.777	5.213	165
170	352.29	0.001770	0.00837	1660.2	2405.4	1690.3	857.4	2547.7	3.808	5.179	170
175	354.67	0.001804	0.00793	1679.4	2390.7	1711.0	818.5	2529.5	3.840	5.143	175
180	356.99	0.001840	0.00750	1699.1	2374.9	1732.2	777.8	2510.0	3.872	5.106	180
185	359.26	0.001881	0.00709	1719.3	2357.9	1754.1	734.9	2489.0	3.905	5.067	185
190	361.47	0.001926	0.00668	1740.3	2339.1	1776.9	689.2	2466.0	3.940	5.026	190
195	363.63	0.001977	0.00627	1762.3	2318.4	1800.9	639.8	2440.7	3.976	4.981	195
200	365.75	0.002038	0.00586	1785.9	2294.8	1826.6	585.4	2412.1	4.015	4.931	200
205	367.81	0.002111	0.00544	1811.7	2267.3	1855.0	523.8	2378.9	4.057	4.875	205
210	369.83	0.002207	0.00499	1841.6	2233.5	1888.0	450.4	2338.4	4.107	4.808	210
215	371.79	0.002349	0.00448	1879.5	2187.4	1930.0	353.6	2283.6	4.171	4.719	215
220	373.71	0.002703	0.00364	1951.6	2092.4	2011.1	161.5	2172.6	4.294	4.544	220
220.64	373.95	0.003106	0.00311	2018.1	2018.1	2086.6	0.0	2086.6	4.410	4.410	220.64
p	T	v_f	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_g	p

SPECIFIC ENTHALPY OF WATER AND STEAM

		kJ/kg																
Pressure (bar)	0.1	0.5	1	5	10	20	40	60	80	100	150	200	220.64	250	300	400	500	1000
Temp (°C)	Critical Isobar																	
0.01	0	0.1	0.1	0.5	1	2	4.1	6.1	8.1	10.1	15.1	20.1	22.1	25	29.9	39.6	49.2	95.4
25	104.8	104.9	104.9	105.3	105.8	106.7	108.5	110.4	112.2	114.1	118.6	123.2	125.1	127.8	132.3	141.3	150.2	194.1
50	2592.0	209.4	209.4	209.8	210.2	211.1	212.8	214.5	216.2	217.9	222.2	226.5	228.3	230.8	235.1	243.6	252.0	293.9
75	2639.8	314.0	314.1	314.4	314.8	315.6	317.2	318.8	320.5	322.1	326.1	330.1	331.8	334.2	338.2	346.2	354.3	394.3
100	2687.5	2682.4	2675.8	419.5	419.8	420.6	422.1	423.6	425.1	426.6	430.4	434.2	435.7	438.0	441.7	449.3	456.9	495.1
125	2735.2	2731.5	2726.7	525.3	525.6	526.3	527.7	529.1	530.5	531.8	535.3	538.8	540.3	542.4	545.9	553.0	560.1	596.3
150	2783.0	2780.2	2776.6	632.2	632.5	633.1	634.4	635.6	636.9	638.1	641.3	644.4	645.8	647.7	650.9	657.4	664.0	697.9
175	2831.2	2828.9	2826.1	2801.4	741.1	741.6	742.7	743.7	744.8	745.9	748.6	751.4	752.6	754.2	757.1	763.0	768.9	800.2
200	2879.6	2877.8	2875.5	2855.8	2828.3	852.5	853.3	854.1	854.9	855.8	858.0	860.3	861.2	862.6	865.0	870.0	875.2	903.4
225	2928.4	2926.8	2924.9	2908.8	2887.0	2836.1	967.1	967.6	968.1	968.7	970.1	971.7	972.4	973.4	975.2	979.0	983.2	1007.6
250	2977.4	2976.1	2974.5	2961.0	2943.1	2903.2	1085.8	1085.7	1085.7	1085.8	1086.1	1086.7	1087.0	1087.4	1088.4	1090.7	1093.5	1113.1
275	3026.9	3025.8	3024.4	3012.9	2997.8	2965.2	2887.3	1210.9	1210.0	1209.3	1207.8	1206.7	1206.4	1206.0	1205.7	1205.8	1206.8	1220.2
300	3076.7	3075.8	3074.5	3064.6	3051.6	3024.2	2961.7	2885.5	2786.5	1343.3	1338.3	1334.4	1333.0	1331.3	1328.9	1325.6	1324.0	1329.1
325	3126.9	3126.1	3125.0	3116.3	3105.0	3081.5	3029.5	2969.5	2898.4	2810.3	1485.6	1475.2	1471.7	1467.3	1461.1	1452.2	1446.4	1440.3
350	3177.5	3176.8	3175.8	3168.1	3158.2	3137.7	3093.3	3043.9	2988.1	2924.0	2693.1	1646.0	1635.6	1623.9	1608.8	1588.8	1576.1	1554.0
375	3228.5	3227.9	3227.0	3220.1	3211.3	3193.2	3154.7	3112.8	3066.9	3016.3	2858.9	2602.6	2337.7	1849.4	1791.8	1742.6	1716.6	1670.8
400	3279.9	3279.3	3278.6	3272.3	3264.5	3248.3	3214.5	3178.2	3139.4	3097.4	2975.7	2816.9	2732.9	2578.6	2152.8	1931.4	1874.4	1791.1
425	3331.8	3331.2	3330.5	3324.9	3317.8	3303.3	3273.2	3241.4	3207.7	3172.0	3072.3	2953.0	2896.1	2805.0	2611.8	2199.0	2060.7	1915.7
450	3384.0	3383.5	3382.8	3377.7	3371.3	3358.2	3331.2	3302.9	3273.3	3242.3	3157.9	3061.7	3017.8	2950.6	2821.0	2511.8	2284.7	2044.7
475	3436.6	3436.2	3435.6	3430.9	3425.1	3413.2	3388.7	3363.4	3337.1	3309.7	3236.6	3155.8	3120.0	3066.2	2966.8	2740.2	2520.0	2178.5
500	3489.7	3489.3	3488.7	3484.5	3479.1	3468.2	3446.0	3423.1	3399.5	3375.1	3310.8	3241.2	3210.8	3165.9	3084.7	2906.5	2722.6	2316.2
550	3597.1	3596.8	3596.3	3592.7	3588.1	3579.0	3560.3	3541.3	3521.8	3502.0	3450.4	3396.1	3373.0	3339.2	3279.7	3154.4	3025.3	2595.9
600	3706.3	3706.0	3705.6	3702.5	3698.6	3690.7	3674.9	3658.7	3642.4	3625.8	3583.1	3539.0	3520.4	3493.5	3446.7	3350.4	3252.5	2865.1
650	3817.2	3816.9	3816.6	3813.9	3810.5	3803.8	3790.1	3776.2	3762.3	3748.1	3712.1	3675.3	3659.8	3637.7	3599.4	3521.6	3443.4	3110.5
700	3929.9	3929.7	3929.4	3927.0	3924.1	3918.2	3906.3	3894.3	3882.2	3870.0	3839.1	3807.8	3794.7	3776.0	3743.9	3679.1	3614.6	3330.7
750	4044.4	4044.2	4043.9	4041.8	4039.3	4034.1	4023.6	4013.2	4002.6	3992.0	3965.2	3938.1	3926.9	3910.9	3883.4	3828.4	3773.9	3530.5
800	4160.6	4160.4	4160.2	4158.4	4156.1	4151.5	4142.3	4133.1	4123.8	4114.5	4091.1	4067.5	4057.7	4043.8	4020.0	3972.6	3925.8	3715.3

SPECIFIC ENTROPY OF WATER AND STEAM

		kJ/kg K																
Pressure (bar)	0.1	0.5	1	5	10	20	40	60	80	100	150	200	220.64	250	300	400	500	1000
Temp (°C)																		
	Critical Isobar																	
0.01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	-0.001	-0.008
25	0.367	0.367	0.367	0.367	0.367	0.367	0.366	0.366	0.365	0.365	0.363	0.362	0.361	0.360	0.359	0.356	0.353	0.337
50	8.174	0.704	0.704	0.704	0.703	0.703	0.702	0.701	0.700	0.699	0.697	0.695	0.694	0.692	0.690	0.686	0.681	0.659
75	8.317	1.016	1.016	1.015	1.015	1.015	1.013	1.012	1.011	1.010	1.006	1.003	1.002	1.000	0.997	0.992	0.986	0.958
100	8.449	7.695	7.361	1.307	1.307	1.306	1.304	1.303	1.301	1.300	1.296	1.292	1.291	1.288	1.285	1.278	1.271	1.237
125	8.573	7.823	7.493	1.581	1.581	1.580	1.578	1.576	1.574	1.573	1.568	1.564	1.562	1.559	1.555	1.546	1.538	1.500
150	8.689	7.941	7.615	1.842	1.841	1.840	1.838	1.836	1.834	1.831	1.826	1.821	1.819	1.816	1.811	1.801	1.791	1.748
175	8.800	8.053	7.728	6.943	2.090	2.089	2.087	2.084	2.081	2.079	2.073	2.066	2.064	2.060	2.054	2.043	2.032	1.982
200	8.905	8.159	7.836	7.061	6.696	2.330	2.327	2.324	2.320	2.317	2.310	2.303	2.300	2.296	2.289	2.275	2.263	2.206
225	9.005	8.260	7.937	7.170	6.817	6.416	2.561	2.557	2.554	2.550	2.541	2.532	2.529	2.524	2.516	2.500	2.485	2.421
250	9.101	8.357	8.035	7.272	6.926	6.547	2.793	2.789	2.784	2.779	2.768	2.757	2.753	2.747	2.737	2.719	2.701	2.628
275	9.194	8.449	8.128	7.369	7.029	6.663	6.231	3.022	3.016	3.010	2.995	2.981	2.976	2.969	2.956	2.934	2.913	2.828
300	9.283	8.539	8.217	7.461	7.125	6.768	6.364	6.070	5.794	3.249	3.228	3.209	3.202	3.192	3.176	3.147	3.122	3.022
325	9.368	8.625	8.303	7.550	7.216	6.866	6.480	6.214	5.985	5.760	3.479	3.449	3.439	3.424	3.402	3.363	3.331	3.212
350	9.451	8.708	8.387	7.635	7.303	6.958	6.584	6.336	6.132	5.946	5.444	3.729	3.707	3.680	3.644	3.587	3.543	3.398
375	9.532	8.788	8.467	7.716	7.386	7.046	6.681	6.444	6.256	6.091	5.705	5.227	4.798	4.034	3.931	3.829	3.764	3.582
400	9.609	8.866	8.545	7.796	7.467	7.129	6.771	6.543	6.366	6.214	5.882	5.553	5.400	5.140	4.476	4.114	4.003	3.764
425	9.685	8.942	8.621	7.872	7.545	7.209	6.857	6.635	6.465	6.323	6.023	5.751	5.638	5.471	5.147	4.504	4.275	3.945
450	9.758	9.015	8.695	7.947	7.620	7.287	6.939	6.722	6.558	6.422	6.143	5.904	5.810	5.676	5.442	4.945	4.590	4.127
475	9.830	9.087	8.766	8.019	7.693	7.361	7.017	6.804	6.645	6.514	6.250	6.032	5.949	5.833	5.640	5.256	4.910	4.309
500	9.900	9.157	8.836	8.089	7.764	7.434	7.092	6.883	6.727	6.599	6.348	6.145	6.068	5.964	5.796	5.474	5.176	4.490
550	10.034	9.291	8.971	8.225	7.901	7.572	7.235	7.031	6.880	6.758	6.523	6.339	6.272	6.182	6.040	5.786	5.556	4.841
600	10.163	9.420	9.100	8.354	8.031	7.704	7.371	7.169	7.022	6.904	6.680	6.507	6.445	6.364	6.237	6.017	5.825	5.158
650	10.287	9.544	9.223	8.478	8.156	7.830	7.499	7.300	7.156	7.041	6.823	6.659	6.601	6.524	6.407	6.208	6.037	5.431
700	10.406	9.663	9.342	8.598	8.275	7.951	7.621	7.425	7.282	7.169	6.957	6.799	6.743	6.670	6.560	6.374	6.218	5.664
750	10.520	9.777	9.457	8.713	8.391	8.067	7.739	7.544	7.403	7.292	7.084	6.930	6.876	6.805	6.700	6.524	6.378	5.864
800	10.631	9.888	9.568	8.824	8.502	8.179	7.852	7.658	7.518	7.408	7.204	7.053	7.000	6.932	6.830	6.661	6.523	6.041

DENSITY OF WATER AND STEAM

Pressure (bar)	kg/m ³																	
	0.1	0.5	1	5	10	20	40	60	80	100	150	200	220.64	250	300	400	500	1000
Temp (°C)	Critical Isobar																	
0.01	999.8	999.8	999.8	1000.0	1000.3	1000.8	1001.8	1002.8	1003.8	1004.8	1007.3	1009.7	1010.7	1012.2	1014.5	1019.2	1023.8	1045.3
25	997.0	997.0	997.0	997.2	997.5	997.9	998.8	999.7	1000.6	1001.5	1003.7	1005.8	1006.7	1008.0	1010.1	1014.3	1018.4	1037.9
50	0.0673	988.0	988.0	988.2	988.4	988.9	989.7	990.6	991.5	992.3	994.4	996.5	997.4	998.6	1000.7	1004.7	1008.7	1027.4
75	0.0624	974.8	974.8	975.0	975.2	975.7	976.6	977.5	978.3	979.2	981.3	983.5	984.4	985.6	987.7	991.8	995.8	1014.6
100	0.0582	0.293	0.590	958.5	958.8	959.2	960.2	961.1	962.0	962.9	965.2	967.4	968.4	969.6	971.8	976.1	980.3	999.8
125	0.0545	0.274	0.550	939.2	939.4	939.9	940.9	941.9	942.9	943.9	946.4	948.8	949.8	951.2	953.5	958.1	962.5	983.1
150	0.0512	0.257	0.516	917.0	917.3	917.9	919.0	920.1	921.2	922.3	925.0	927.7	928.8	930.3	932.9	937.9	942.7	964.8
175	0.0484	0.243	0.487	2.503	892.4	893.0	894.3	895.6	896.8	898.1	901.1	904.1	905.4	907.1	909.9	915.5	920.9	945.0
200	0.0458	0.230	0.460	2.353	4.850	865.0	866.5	868.0	869.5	870.9	874.5	878.0	879.4	881.3	884.6	890.9	897.0	923.7
225	0.0435	0.218	0.437	2.223	4.550	9.63	835.1	836.9	838.7	840.4	844.7	848.8	850.5	852.8	856.6	864.0	870.9	901.0
250	0.0414	0.207	0.416	2.108	4.300	8.97	798.9	801.2	803.5	805.7	811.0	816.1	818.1	820.9	825.6	834.3	842.4	876.7
275	0.0395	0.198	0.396	2.006	4.070	8.43	18.31	759.1	762.2	765.1	772.2	778.7	781.3	784.8	790.6	801.4	811.1	850.8
300	0.0378	0.189	0.379	1.913	3.880	7.97	16.99	27.63	41.2	715.3	725.6	734.7	738.2	743.0	750.7	764.4	776.5	823.2
325	0.0362	0.181	0.363	1.830	3.700	7.57	15.93	25.39	36.5	50.3	664.9	679.8	685.3	692.4	703.4	722.0	737.6	793.7
350	0.0348	0.174	0.348	1.754	3.540	7.21	15.04	23.67	33.4	44.6	87.1	600.6	612.0	625.5	643.9	671.9	693.2	762.3
375	0.0334	0.167	0.335	1.684	3.390	6.90	14.28	22.27	31.0	40.7	71.9	130.3	210.0	505.5	558.2	609.3	641.2	728.8
400	0.0322	0.161	0.322	1.620	3.260	6.61	13.62	21.09	29.1	37.8	63.8	100.5	121.9	166.5	357.4	523.3	577.8	692.9
425	0.0310	0.155	0.311	1.561	3.140	6.35	13.03	20.07	27.5	35.5	58.3	87.1	101.8	126.8	188.7	394.1	497.7	654.7
450	0.0300	0.150	0.300	1.506	3.030	6.11	12.49	19.17	26.2	33.6	54.1	78.6	90.3	109.0	148.4	270.9	402.0	614.2
475	0.0290	0.145	0.290	1.454	2.920	5.90	12.01	18.37	25.0	31.9	50.8	72.4	82.4	97.8	128.1	210.0	315.2	571.7
500	0.0280	0.140	0.280	1.407	2.820	5.69	11.57	17.65	23.9	30.5	48.0	67.6	76.4	89.7	115.1	177.8	257.1	528.3
550	0.0263	0.132	0.263	1.320	2.650	5.33	10.79	16.39	22.1	28.0	43.6	60.3	67.7	78.5	98.3	143.2	195.4	444.6
600	0.0248	0.124	0.248	1.244	2.490	5.01	10.12	15.32	20.6	26.1	40.1	55.0	61.4	70.7	87.4	123.6	163.7	374.2
650	0.0235	0.117	0.235	1.176	2.360	4.73	9.53	14.40	19.4	24.4	37.3	50.8	56.5	64.8	79.4	110.5	143.7	321.0
700	0.0223	0.111	0.223	1.115	2.230	4.48	9.01	13.60	18.2	22.9	34.9	47.3	52.5	60.1	73.2	100.7	129.6	282.0
750	0.0212	0.106	0.212	1.060	2.120	4.25	8.55	12.88	17.3	21.7	32.9	44.4	49.2	56.2	68.2	93.1	118.8	253.0
800	0.020	0.101	0.202	1.010	2.020	4.05	8.14	12.25	16.4	20.6	31.1	41.9	46.4	52.8	64.0	86.8	110.2	230.6

SPECIFIC INTERNAL ENERGY OF WATER AND STEAM

Pressure (bar)	kJ/kg																					
	0.1	0.5	1	5	10	20	40	60	80	100	150	200	220.64	250	300	400	500	1000				
Temp (°C)													Critical Isobar									
0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-0.2			
25	104.8	104.8	104.8	104.8	104.7	104.7	104.5	104.4	104.2	104.1	103.7	103.3	103.2	102.9	102.6	101.9	101.1	101.1	97.7			
50	2443.3	209.3	209.3	209.3	209.2	209.0	208.7	208.4	208.2	207.9	207.1	206.4	206.2	205.8	205.1	203.7	202.5	202.5	196.6			
75	2479.5	314.0	314.0	313.9	313.8	313.6	313.1	312.7	312.3	311.9	310.8	309.8	309.4	308.8	307.8	305.9	304.1	304.1	295.8			
100	2515.5	2511.5	2506.2	418.9	418.8	418.5	417.9	417.4	416.8	416.2	414.8	413.5	412.9	412.2	410.9	408.4	405.9	405.9	395.1			
125	2551.6	2548.7	2545.0	524.7	524.5	524.2	523.4	522.7	522.0	521.2	519.5	517.8	517.1	516.1	514.4	511.2	508.2	508.2	494.6			
150	2587.9	2585.7	2582.9	631.6	631.4	630.9	630.0	629.1	628.2	627.3	625.1	622.9	622.0	620.8	618.7	614.8	611.0	611.0	594.3			
175	2624.5	2622.8	2620.6	2601.6	740.0	739.4	738.2	737.0	735.9	734.8	732.0	729.3	728.2	726.7	724.1	719.3	714.6	714.6	694.4			
200	2661.3	2660.0	2658.2	2643.3	2622.2	850.1	848.6	847.2	845.7	844.3	840.8	837.5	836.1	834.2	831.1	825.1	819.4	819.4	795.1			
225	2698.5	2697.4	2695.9	2683.9	2667.3	2628.5	962.3	960.5	958.6	956.8	952.4	948.1	946.4	944.1	940.2	932.7	925.8	925.8	896.6			
250	2736.1	2735.1	2733.9	2723.8	2710.4	2680.2	1080.8	1078.2	1075.8	1073.4	1067.6	1062.2	1060.0	1057.0	1052.0	1042.7	1034.2	1034.2	999.1			
275	2774.0	2773.2	2772.1	2763.6	2752.3	2727.8	2668.9	1203.0	1199.5	1196.2	1188.3	1181.0	1178.1	1174.2	1167.7	1155.9	1145.2	1145.2	1102.7			
300	2812.3	2811.6	2810.6	2803.2	2793.6	2773.2	2726.2	2668.4	2592.3	1329.4	1317.6	1307.1	1303.1	1297.6	1288.9	1273.3	1259.6	1259.6	1207.6			
325	2850.9	2850.3	2849.5	2843.0	2834.7	2817.2	2778.3	2733.1	2679.2	2611.6	1463.0	1445.8	1439.5	1431.2	1418.4	1396.7	1378.6	1378.6	1314.3			
350	2890.0	2889.4	2888.7	2883.0	2875.7	2860.5	2827.4	2790.4	2748.3	2699.6	2520.9	1612.7	1599.6	1583.9	1562.2	1529.3	1503.9	1503.9	1422.8			
375	2929.5	2929.0	2928.3	2923.2	2916.7	2903.3	2874.7	2843.4	2808.9	2770.7	2650.4	2449.1	2232.6	1799.9	1738.1	1677.0	1638.6	1638.6	1533.6			
400	2969.3	2968.9	2968.3	2963.7	2957.9	2945.9	2920.7	2893.7	2864.6	2833.1	2740.6	2617.9	2551.9	2428.5	2068.9	1854.9	1787.8	1787.8	1646.8			
425	3009.6	3009.2	3008.7	3004.5	2999.2	2988.5	2966.1	2942.4	2917.2	2890.4	2815.0	2723.5	2679.3	2607.8	2452.8	2097.5	1960.2	1960.2	1762.9			
450	3050.3	3049.9	3049.4	3045.6	3040.9	3031.1	3011.0	2989.9	2967.8	2944.5	2880.7	2807.2	2773.4	2721.2	2618.9	2364.2	2160.3	2160.3	1881.9			
475	3091.4	3091.0	3090.6	3087.1	3082.8	3073.9	3055.7	3036.7	3017.0	2996.5	2941.3	2879.7	2852.1	2810.5	2732.7	2549.7	2361.4	2361.4	2003.6			
500	3132.9	3132.6	3132.2	3129.0	3125.0	3116.9	3100.3	3083.1	3065.4	3047.0	2998.4	2945.3	2922.0	2887.3	2824.0	2681.6	2528.1	2528.1	2126.9			
550	3217.2	3217.0	3216.6	3213.9	3210.5	3203.6	3189.5	3175.2	3160.5	3145.4	3106.2	3064.7	3046.9	3020.8	2974.5	2875.0	2769.5	2769.5	2371.0			
600	3303.3	3303.1	3302.8	3300.4	3297.5	3291.5	3279.4	3267.2	3254.7	3242.0	3209.3	3175.3	3160.9	3140.0	3103.4	3026.8	2947.1	2947.1	2597.9			
650	3391.2	3391.0	3390.7	3388.6	3386.0	3380.8	3370.3	3359.6	3348.9	3337.9	3310.1	3281.4	3269.3	3251.9	3221.7	3159.5	3095.6	3095.6	2798.9			
700	3480.8	3480.6	3480.4	3478.5	3476.2	3471.6	3462.4	3453.0	3443.6	3434.0	3409.8	3385.1	3374.7	3359.9	3334.3	3282.0	3228.7	3228.7	2976.1			
750	3572.2	3572.0	3571.8	3570.2	3568.1	3564.0	3555.8	3547.5	3539.1	3530.7	3509.4	3487.7	3478.7	3465.8	3443.6	3398.6	3353.1	3353.1	3135.2			
800	3665.3	3665.2	3665.0	3663.6	3661.7	3658.0	3650.6	3643.2	3635.7	3628.2	3609.2	3590.1	3582.1	3570.7	3551.2	3511.8	3472.2	3472.2	3281.7			

TRANSPORT PROPERTIES OF SATURATED WATER & STEAM

Temp. °C	Specific volume m ³ /kg		Isobaric specific heat capacity kJ/kg K		Thermal conductivity W/m K		Dynamic viscosity kg/s m		Prandtl number $=\mu c_p/\lambda$		Temp. °C
	v_f	v_g	c_{p_f}	c_{p_g}	λ_f	λ_g	$\mu_f/10^{-3}$	$\mu_g/10^{-6}$	Pr_f	Pr_g	
0.01	0.00100	206.2	4.217	1.854	0.569	0.0173	1.755	8.8	13.02	0.942	0.01
10	0.00100	106.4	4.193	1.860	0.587	0.0185	1.301	9.1	9.29	0.915	10
20	0.00100	57.8	4.182	1.866	0.603	0.0191	1.002	9.4	6.95	0.918	20
30	0.00100	32.9	4.179	1.885	0.618	0.0198	0.797	9.7	5.39	0.923	30
40	0.00101	19.5	4.179	1.885	0.632	0.0204	0.651	10.1	4.31	0.930	40
50	0.00101	12.05	4.181	1.899	0.643	0.0210	0.544	10.4	3.53	0.939	50
60	0.00102	7.68	4.185	1.915	0.653	0.0217	0.462	10.7	2.96	0.947	60
70	0.00102	5.05	4.190	1.936	0.662	0.0224	0.400	11.1	2.53	0.956	70
80	0.00103	3.41	4.197	1.962	0.670	0.0231	0.350	11.4	2.19	0.966	80
90	0.00104	2.36	4.205	1.992	0.676	0.0240	0.311	11.7	1.93	0.976	90
100	0.00104	1.673	4.216	2.028	0.681	0.0249	0.278	12.1	1.723	0.986	100
125	0.00107	0.770	4.254	2.147	0.687	0.0272	0.219	13.3	1.358	1.047	125
150	0.00109	0.392	4.310	2.314	0.687	0.0300	0.180	14.4	1.133	1.110	150
175	0.00112	0.217	4.389	2.542	0.679	0.0334	0.153	15.6	0.990	1.185	175
200	0.00116	0.127	4.497	2.843	0.665	0.0375	0.133	16.7	0.902	1.270	200
225	0.00120	0.0783	4.648	3.238	0.644	0.0427	0.1182	17.9	0.853	1.36	225
250	0.00125	0.0500	4.867	3.772	0.616	0.0495	0.1065	19.1	0.841	1.45	250
275	0.00132	0.0327	5.202	4.561	0.582	0.0587	0.0972	20.2	0.869	1.56	275
300	0.00140	0.0216	5.762	5.863	0.541	0.0719	0.0897	21.4	0.955	1.74	300
325	0.00153	0.0142	6.861	8.440	0.493	0.0929	0.0790	23.0	1.100	2.09	325
350	0.00174	0.00880	10.10	17.15	0.437	0.1343	0.0648	25.8	1.50	3.29	350
360	0.00190	0.00694	14.6	25.1	0.400	0.168	0.0582	27.5	2.11	3.89	360
374.15	0.00317	0.00317	∞	∞	0.24	0.24	0.045	45.0	∞	∞	374.15

TRANSPORT PROPERTIES OF STEAM

Temp. °C	Isobaric sp. heat capacity kJ/kg K c_p	Thermal conductivity W/m K λ	Dynamic viscosity kg/s m $\mu/10^{-6}$	Prandtl number $Pr = \mu c_p / \lambda$
100	2.028	0.0245	12.1	0.986
200	1.979	0.0331	16.2	0.968
300	2.010	0.0434	20.4	0.946
400	2.067	0.0548	24.6	0.928
500	2.132	0.0673	28.8	0.912
600	2.201	0.0805	32.9	0.898
700	2.268	0.0942	36.8	0.887
800	2.332	0.1080	40.6	0.876

Values for water at atmospheric pressure between 0°C and 100°C are given with sufficient accuracy by the saturated values in the previous table.

The above values are correct for a pressure of 1 atm = 1.01325 bar but may be used with sufficient accuracy at other pressures.

TRANSPORT PROPERTIES OF AIR

Temp. °C	Isobaric sp. heat capacity kJ/kg K c_p	Thermal conductivity W/m K λ	Dynamic viscosity kg/s m $\mu/10^{-6}$	Prandtl number $Pr = \mu c_p / \lambda$
-100	1.01	0.016	12	0.75
0	1.01	0.024	17	0.72
100	1.02	0.032	22	0.70
200	1.03	0.039	26	0.69
300	1.05	0.045	30	0.69
400	1.07	0.051	33	0.70
500	1.10	0.056	36	0.70
600	1.12	0.061	39	0.71
700	1.14	0.066	42	0.72
800	1.16	0.071	44	0.73

This table may be used with reasonable accuracy for values of c_p , γ , μ and Pr of N₂, O₂ and CO.

The above values are correct for a pressure of 1 atm = 1.01325 bar but may be used with sufficient accuracy at other pressures.

TRANSPORT PROPERTIES OF CARBON DIOXIDE

Temp. °C	Isobaric sp. heat capacity kJ/kg K c_p	Thermal conductivity W/m K λ	Dynamic viscosity kg/s m $\mu/10^{-6}$	Prandtl number $Pr = \mu c_p / \lambda$
-50	0.79	0.011	11	0.79
0	0.83	0.015	14	0.78
100	0.92	0.022	18	0.75
200	1.00	0.030	22	0.73
300	1.06	0.038	26	0.72
400	1.11	0.046	29	0.71
500	1.16	0.053	32	0.70
600	1.20	0.061	35	0.69
700	1.23	0.069	38	0.68
800	1.25	0.078	41	0.67

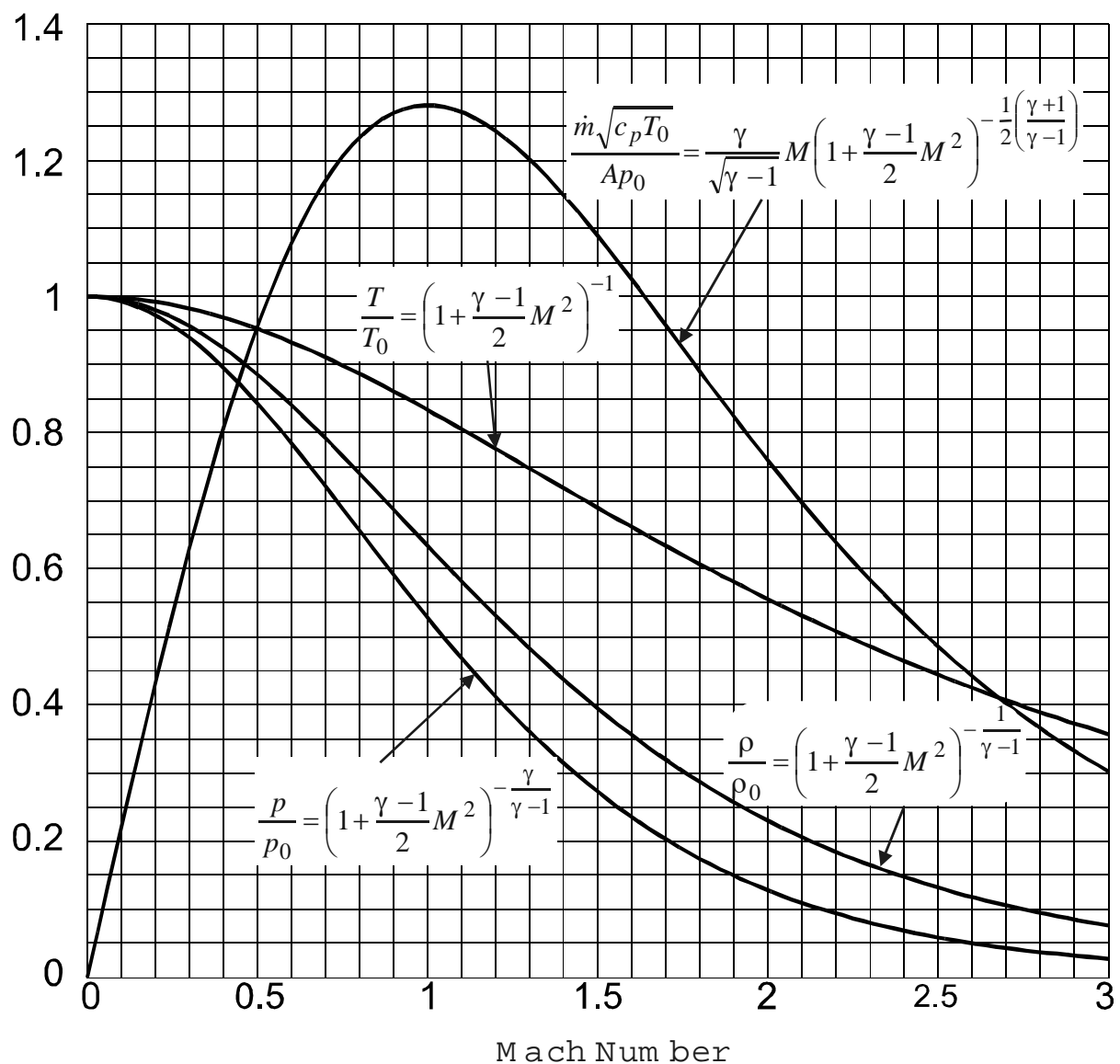
The above values are correct for a pressure of 1 atm = 1.01325 bar but may be used with sufficient accuracy at other pressures.

TRANSPORT PROPERTIES OF HYDROGEN

Temp. °C	Isobaric sp. heat capacity kJ/kg K c_p	Thermal conductivity W/m K λ	Dynamic viscosity kg/s m $\mu/10^{-6}$	Prandtl number $Pr = \mu c_p / \lambda$
-200	10.6	0.050	3.3	0.71
-100	13.1	0.112	6.2	0.72
0	14.2	0.172	8.4	0.69
100	14.5	0.220	10.3	0.68
200	14.5	0.307	12.1	0.67
300	14.5	0.307	13.8	0.66
400	14.6	0.348	15.4	0.65
500	14.7	0.387	16.9	0.64
600	14.8	0.427	18.3	0.63
700	14.9	0.476	19.9	0.62
800	15.1	0.528	21.1	0.61

The above values are correct for a pressure of 1 atm = 1.01325 bar but may be used with sufficient accuracy at other pressures.

PERFECT GAS RELATIONS FOR COMPRESSIBLE FLOW FOR $\gamma=1.4$



Notes:

- (1) $T_0 = \text{const.}$ in adiabatic flow with no shaft work
- (2) If flow is isentropic, $p_0 = \text{const.}$ and $\rho_0 = \text{const.}$ when $T_0 = \text{const.}$

- (3) At Mach 1 and when $\gamma=1.4$, $\frac{\dot{m}\sqrt{c_p T_0}}{A p_0} = 1.281$

PROPERTIES OF GASES AT SEA LEVEL CONDITIONS

The following data are at $p_{sl} = 1.01325 \text{ bar}$ and $T_{sl} = 15^\circ\text{C}$.

	<i>Air</i>	<i>CO₂</i>	<i>H₂</i>	<i>He</i>
Density $\rho \text{ kg/m}^3$	1.225	1.860	0.0852	0.1693
Viscosity $\mu \text{ kg/m s}$	17.9×10^{-6}	14.4×10^{-6}	8.9×10^{-6}	19.7×10^{-6}
Kinematic viscosity $\nu \text{ m}^2/\text{s}$	14.64×10^{-6}	7.7×10^{-6}	104×10^{-6}	116×10^{-6}
Speed of sound m/s	340	264	1292	988
Thermal conductivity $\lambda \text{ W/m K}$	0.0252	0.0153	0.180	0.150

PROPERTIES OF LIQUIDS AT SEA LEVEL CONDITIONS

The following data are at $p_{sl} = 1.01325 \text{ bar}$ and $T_{sl} = 15^\circ\text{C}$.

	<i>Hg</i>	<i>H₂O</i>
Density $\rho \text{ kg/m}^3$	13595.1	1000
Viscosity $\mu \text{ kg/m s}$	1.59×10^{-3}	1.14×10^{-3}
Kinematic viscosity $\nu \text{ m}^2/\text{s}$	0.117×10^{-6}	1.14×10^{-6}
Thermal conductivity $\lambda \text{ W/m K}$	8.36	0.620

THE INTERNATIONAL STANDARD ATMOSPHERE

The sea-level condition for the international standard atmosphere is given by

$$p_{sl} = 1.01325 \text{ bar} = 760 \text{ mm Hg}$$

$$T_{sl} = 15^\circ\text{C} = 288.15 \text{ K}$$

for which

$$\rho_{sl} = 1.225 \text{ kg/m}^3$$

$$\nu_{sl} = \frac{\mu_{sl}}{\rho_{sl}} = 14.64 \times 10^{-6} \text{ m}^2/\text{s}$$

$$a_{sl} = \sqrt{\gamma R T_{sl}} = 340 \text{ m/s}$$

PROPERTIES OF THE INTERNATIONAL STANDARD ATMOSPHERE AT ALTITUDE

Height m	$\frac{T}{T_{sl}}$	$\frac{p}{p_{sl}}$	$\frac{\rho}{\rho_{sl}}$	$\frac{\nu}{\nu_{sl}}$
0	1.0000	1.0000	1.0000	1.0000
1000	0.9774	0.8870	0.9075	1.0826
2000	0.9549	0.7846	0.8217	1.1739
3000	0.9324	0.6920	0.7422	1.2753
4000	0.9098	0.6085	0.6689	1.3881
5000	0.8873	0.5334	0.6012	1.5138
6000	0.8648	0.4660	0.5389	1.6543
7000	0.8423	0.4057	0.4816	1.8117
8000	0.8198	0.3519	0.4292	1.9887
9000	0.7973	0.3040	0.3813	2.1881
10000	0.7748	0.2615	0.3376	2.4137
11000	0.7523	0.2240	0.2978	2.6697
12000	0.7519	0.1915	0.2546	3.1206
13000	0.7519	0.1636	0.2176	3.6514
14000	0.7519	0.1398	0.1860	4.2722
15000	0.7519	0.1195	0.1590	4.9983
16000	0.7519	0.1022	0.1359	5.8476
17000	0.7519	0.0873	0.1162	6.8408
18000	0.7519	0.0747	0.0993	8.0023
19000	0.7519	0.0638	0.0849	9.3606
20000	0.7519	0.0546	0.0726	10.9488
21000	0.7551	0.0467	0.0618	12.9031
22000	0.7585	0.0399	0.0527	15.2021
23000	0.7620	0.0342	0.0449	17.8964
24000	0.7654	0.0293	0.0383	21.0515
25000	0.7689	0.0252	0.0327	24.7434
26000	0.7723	0.0216	0.0280	29.0603
27000	0.7758	0.0186	0.0239	34.1039
28000	0.7792	0.0160	0.0205	39.9926
29000	0.7826	0.0137	0.0175	46.8626
30000	0.7861	0.0118	0.0150	54.8714

The speed of sound at altitude is given by

$$\frac{a}{a_{sl}} = \sqrt{\frac{T}{T_{sl}}}$$

The viscosity at altitude is given approximately by

$$\mu = \frac{1.458 \times 10^{-6} T^{3/2}}{T + 110.4} \text{ kg/m.s}$$

PHYSICAL CONSTANTS

Absolute zero of temperature	-273.15°C
Acceleration due to gravity, g	9.80665 m/s ²
Avogadro's number, N_A	6.022x10 ²⁶ kmol ⁻¹
Base of natural logarithms, e	2.7182818
Boltzmann's constant, k	1.381 x 10 ⁻²³ J/K
Electronic charge, e	-1.602 x 10 ⁻¹⁹ C
Faraday's constant, F	9.648 x 10 ⁷ C/kmol
Universal Gas constant, \bar{R}	8.3143 kJ/kmol K
Permeability of vacuum, μ_0	1.257 x 10 ⁻⁶ H/m
Permittivity of vacuum, ϵ_0	8.854 x 10 ⁻¹² F/m
Pi, π	3.14159265
Planck's constant, h	6.626 x 10 ⁻³⁴ J/s
Stefan-Boltzmann's constant, σ	5.67x10 ⁻⁸ W/m ² K ⁴
Velocity of light in vacuum, c	2.998 x 10 ⁸ m/s
Volume of perfect gas at STP	22.41 m ³ /kmol

CONVERSION OF NON-SI TO SI UNITS

Non SI Unit	Conversion		SI Unit
Length			
1 yard (yd)		= 0.9144	m
1 foot (ft)	=	0.9144/3.0	≈ 0.3048 m
1 inch (in)	=	0.9144/36.0	≈ 0.0254 m
1 mile (mile)	=	0.9144×1760	≈ 1609 m
Mass			
1 pound (lb)		= 0.45359237	kg
1 ounce (oz)	=	0.45359237/16	≈ 0.02835 kg
1 hundredweight (cwt)	=	0.45359237×112	≈ 50.8 kg
1 tonne (t)	=		= 1000 kg
1 ton (ton)	=	0.45359237×2240	≈ 1016 kg
Force			
1 dyne (dyn)		= 10^{-5}	N
1 ounce (ozf)	=	0.45359237×9.80665/16	≈ 0.278 N
1 pound force (lbf)	=	0.45359237×9.80665	≈ 4.45 N
1 ton force (tonf)	=	0.45359237×9.80665×2240	≈ 9960 N
Volume			
1 Imperial gallon (gal)		= 0.0045460916	m ³
1 pint (pt)	=	0.0045460916/8	≈ 0.0005683 m ³
1 litre (l)		= 0.001	m ³
Dynamic Viscosity			
1 poise (P)		= 0.1	Ns/m ²

CONVERSION OF NON-SI TO SI UNITS cont.

Non SI Unit	Conversion		SI Unit
Kinematic Viscosity			
1 stokes (St)	=	10^{-4}	m^2/s
Energy			
1 erg	=	10^{-7}	J
1 calorie (cal)	=	4.1868	J
1 Cal (kcal)	=	4186.8	J
1 Btu	=	$4.1868 \times 0.45359237 / 1.8$	≈ 1055 J
Power			
1 horsepower (hp)	=	$550 \times \left(\frac{0.9144}{3} \right) \times 0.45359237 \times 9.80665$	≈ 746 W
Pressure			
1 dyn/cm ²	=	0.1	Pa
1 N/m ²	=	1	Pa
1 mm H ₂ O	=	$1000 \times 0.001 \times 9.80665$	= 9.80665 Pa
1 mm Hg	=	$13595.1 \times 0.001 \times 9.80665$	= 133.32 Pa
1 torr	=	$101325 / 760$	= 133.32 Pa
1 in Hg	=	$13595.1 \times 9.80665 \times \frac{0.9144}{36}$	= 3386 Pa
1 lb/in ²	=	$0.45359237 \times 9.80665 \times \left(\frac{36}{0.9144} \right)^2$	= 6895 Pa
1 bar	=	100000	Pa
1 atm	=	101325	Pa
1 kgf/mm ²	=	$1 \times 9.80665 \times 1000000$	= 9806650 Pa

SOURCES OF INFORMATION

Haywood, RW, "Thermodynamic Tables in SI (metric) Units", 3rd Edition, CUP.

Gas Flow Tables, CUED, 1975.

Houghton E.L., Brock A.E., "Tables for compressible flow of dry air: giving major parameters for the Mach number range 0 to 4", 3rd Edition, London, 1975

Kay, GWC, and Laby, TH, "Tables of Physical and Chemical Constants and Some Mathematic Functions" 14th Ed, Longman, 1972

US Standard Atmosphere, NOAA-S/T 76-1562, 1976

The Pressure-Enthalpy chart for the refrigerant HFC-134a is reproduced with the kind permission of DuPont.

CRITICAL POINT DATA FOR REFRIGERANT R-134a (CH₂FCF₃)

Critical Temperature = 101.08 °C
Critical Pressure = 40.603 bar
Critical Volume = 0.0019 m³/kg
Molecular Weight = 102.03 kg/kMol

PROPERTIES TABLE FOR REFRIGERANT R-134a (CH₂FCF₃)

Saturation Temp. °C	Saturation Pressure bar	Saturated						Superheated by				Saturation Temp. °C
		Specific volume m ³ /kg		Specific enthalpy kJ/kg		Specific entropy kJ/kg K		20K		40K		
		<i>v_f</i>	<i>v_g</i>	<i>h_f</i>	<i>h_g</i>	<i>s_f</i>	<i>s_g</i>	<i>h</i>	<i>s</i>	<i>h</i>	<i>s</i>	
<i>T_{sat}</i>	<i>P_{sat}</i>	<i>v_f</i>	<i>v_g</i>	<i>h_f</i>	<i>h_g</i>	<i>s_f</i>	<i>s_g</i>	<i>h</i>	<i>s</i>	<i>h</i>	<i>s</i>	<i>T_{sat}</i>
-45	0.39	0.00070	0.46458	141.9	370.8	0.7687	1.7722	385.8	1.8348	401.3	1.8949	-45
-40	0.51	0.00071	0.36094	148.1	374.0	0.7956	1.7643	389.2	1.8270	405.0	1.8869	-40
-35	0.66	0.00071	0.28390	154.4	377.2	0.8221	1.7574	392.7	1.8201	408.6	1.8797	-35
-30	0.84	0.00072	0.22585	160.8	380.3	0.8483	1.7512	396.1	1.8139	412.3	1.8734	-30
-25	1.06	0.00073	0.18155	167.2	383.4	0.8743	1.7458	399.5	1.8085	416.0	1.8678	-25
-20	1.33	0.00074	0.14735	173.6	386.5	0.8999	1.7410	402.9	1.8037	419.7	1.8629	-20
-15	1.64	0.00074	0.12065	180.1	389.6	0.9253	1.7368	406.3	1.7995	423.4	1.8587	-15
-10	2.01	0.00075	0.09959	186.7	392.7	0.9505	1.7331	409.7	1.7959	427.0	1.8550	-10
-5	2.43	0.00076	0.08281	193.3	395.6	0.9753	1.7299	413.1	1.7927	430.7	1.8518	-5
0	2.93	0.00077	0.06933	200.0	398.6	1.0000	1.7270	416.4	1.7900	434.3	1.8491	0
5	3.50	0.00078	0.05840	206.8	401.5	1.0244	1.7245	419.7	1.7877	437.9	1.8469	5
10	4.15	0.00079	0.04947	213.6	404.3	1.0486	1.7222	422.9	1.7857	441.5	1.8450	10
15	4.88	0.00080	0.04212	220.5	407.1	1.0726	1.7202	426.1	1.7840	445.0	1.8434	15
20	5.72	0.00082	0.03602	227.5	409.8	1.0965	1.7183	429.3	1.7825	448.5	1.8422	20
25	6.65	0.00083	0.03093	234.6	412.3	1.1202	1.7165	432.3	1.7813	452.0	1.8412	25
30	7.70	0.00084	0.02666	241.7	414.8	1.1438	1.7148	435.4	1.7803	455.4	1.8405	30
35	8.87	0.00086	0.02305	249.0	417.2	1.1672	1.7130	438.3	1.7794	458.8	1.8399	35
40	10.17	0.00087	0.01999	256.4	419.4	1.1906	1.7112	441.2	1.7786	462.1	1.8395	40
45	11.60	0.00089	0.01736	263.9	421.5	1.2140	1.7093	444.0	1.7779	465.4	1.8393	45
50	13.18	0.00091	0.01511	271.6	423.4	1.2374	1.7073	446.7	1.7772	468.6	1.8392	50
60	16.82	0.00095	0.01148	287.5	426.6	1.2846	1.7022	451.8	1.7759	474.8	1.8392	60
70	21.16	0.00101	0.00871	304.3	428.6	1.3329	1.6953	456.4	1.7743	480.7	1.8394	70
80	26.33	0.00108	0.00654	322.4	428.8	1.3834	1.6848	460.4	1.7722	486.2	1.8395	80
90	32.45	0.00119	0.00481	342.9	425.4	1.4393	1.6665	463.8	1.7692	491.3	1.8392	90
100	39.73	0.00148	0.00345	373.3	407.7	1.5183	1.6105	466.4	1.7650	495.9	1.8384	100

Enthalpy-Entropy Diagram for Steam

Plotted from the IAPWS equations <http://www.iapws.org> (Dumcun A. Simpson (2002))

