PROPERTIES OF SOME GASES AND LIQUIDS AT ONE ATMOSPHERE
(Ar, CO_2, He, N_2, $H_2\,O_{(\ell)}$)

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by

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The thermodynamic and transport properties of various gases and liquids have been correlated with temperature. Gaseous argon, carbon dioxide, helium and nitrogen as well as liquid water have been examined over a wide range of temperatures. A non-linear least squares algorithm is used based on a procedure developed by Marquardt (1963), which combines the Gauss or Taylor series method and the method of steepest descent. The form of the correlation chosen for a particular property is based on known behaviour such as perfect gas, or a simple polynomial or power law fit if the behaviour is unknown. In most cases the given equation is accurate within the range specified for the data in the original source. The following properties are considered:

ρ	-	density
μ	-	dynamic viscosity
κ	-	thermal conductivity
C_p	-	specific heat at constant pressure
α	-	thermal diffusivity
ρ/μ	-	Reynolds number group; $\mathrm{Re}_L = (\rho/\mu)UL$
$g\beta/\nu\alpha$	-	Rayleigh number group; $\mathrm{Ra}_L = (g\beta/\nu\alpha)\Delta T L^3$

ARGON

TEMPERATURE RANGE: 200 - 400 K

PROPERTY	SOURCE	AVG. DEV (%)	MAX. DEV (%)	UNITS
ρ	Hilsenrath (1955)	0.013	0.032 @ 200 K	kg/m^3
μ	Touloukian (1970)	0.030	0.064 @ 200 K	$10^{-6}(N \cdot s)/m^2$
κ	Touloukian (1970)	0.115	0.259 @ 200 K	$W/(m \cdot K)$
C_p	Touloukian (1970)	0.014	0.034 @ 200 K	$J/(kg \cdot K)$
α	calc	0.036	0.071 @ 220 K	m^2/s
ρ/μ	calc	0.015	0.034 @ 280 K	s/m^2
$g\beta/\nu\alpha$	calc	0.057	0.106 @ 220 K	$10^6/(m^3 \cdot K)$

$$\rho = \frac{485.33}{T} + \frac{545.52}{T^2} \text{ (perfect gas + correction term)}$$

$$\mu = \frac{1.9263\ T^{3/2}}{140.54\ +\ T} \text{ (Sutherland's equation [Reid (1966)])}$$

$$\kappa = \frac{1.5359 \times 10^{-3}\ T^{3/2}}{150.12\ +\ T} \text{ (Sutherland's equation [Reid (1966)])}$$

$$C_p = 531.63\ -\ 5.5815 \times 10^{-2}\ T\ +\ 7.3878 \times 10^{-5}\ T^2$$

$$\alpha = 1.2280 \times 10^{-6}\ -\ 1.5062 \times 10^{-8}\ T\ +\ 3.2629 \times 10^{-10}\ T^2 - 1.9055 \times 10^{-13}\ T^3$$

$$\frac{\rho}{\mu} = \frac{2.5146 \times 10^8}{T^{3/2}} + \frac{3.5975 \times 10^{10}}{T^{5/2}}$$

$$\frac{g\beta}{\nu\alpha} = [1.0017 \times 10^{-2}\ -\ 1.7294 \times 10^{-4}\ T\ +\ 1.5168 \times 10^{-6}\ T^2]^{-2}$$

CARBON DIOXIDE

TEMPERATURE RANGE: 220 - 400 K

PROPERTY	SOURCE	AVG. DEV (%)	MAX. DEV (%)	UNITS
ρ	Hilsenrath (1955)	0.066	0.160 @ 220 K	kg/m^3
μ	Touloukian (1970)	0.038	0.102 @ 250 K	$10^{-6}(N \cdot s)/m^2$
κ	Touloukian (1970)	0.066	0.125 @ 270 K	$W/(m \cdot K)$
C_p	Hilsenrath (1955)	0.066	0.169 @ 220 K	$J/(kg \cdot K)$
α	calc	0.072	0.147 @ 210 K	m^2/s
ρ/μ	calc	0.067	0.127 @ 220 K	s/m^2
$g\beta/\nu\alpha$	calc	0.098	0.266 @ 220 K	$10^6/(m^3 \cdot K)$

$$\rho = \frac{529.03}{T} + \frac{3106.4}{T^2} \text{ (perfect gas + correction term)}$$

$$\mu = -0.33069 + 5.6034 \times 10^{-2}\, T - 1.6558 \times 10^{-5}\, T^2$$

$$\kappa = 3.3535 \times 10^{-3} - 1.0296 \times 10^{-5}\, T + 2.54080 \times 10^{-7}\, T^2 - 2.4389 \times 10^{-10}\, T^3$$

$$C_p = 828.25 - 1.5994\, T + 8.2731 \times 10^{-3}\, T^2 - 8.9253 \times 10^{-6}\, T^3$$

$$\alpha = 5.9146 \times 10^{-7} - 1.4936 \times 10^{-8}\, T + 1.9233 \times 10^{-10}\, T^2 - 9.5262 \times 10^{-14}\, T^3$$

$$\frac{\rho}{\mu} = \frac{3.4802 \times 10^{8}}{T^{3/2}} + \frac{8.2280 \times 10^{10}}{T^{5/2}}$$

$$\frac{g\beta}{\nu\alpha} = [-1.0879 \times 10^{-2} + 1.6148 \times 10^{-4}\, T - 1.0022 \times 10^{-6}\, T^2]^{-2}$$

HELIUM

TEMPERATURE RANGE: 200 - 400 K

PROPERTY	SOURCE	AVG. DEV (%)	MAX. DEV (%)	UNITS
ρ	McCarty (1962) Tsederberg (1971)	0.017	0.049 @ 250 K	kg/m^3
μ	Touloukian (1970)	0.050	0.084 @ 210 K	$10^{-6}(N \cdot s)/m^2$
κ	Touloukian (1970)	0.043	0.115 @ 240 K	$W/(m \cdot K)$
C_p	Touloukian (1970)	—	—	$J/(kg \cdot K)$
α	calc	0.080	0.162 @ 240 K	m^2/s
ρ/μ	calc	0.048	0.096 @ 400 K	s/m^2
$g\beta/\nu\alpha$	calc	0.164	0.336 @ 400 K	$10^6/(m^3 \cdot K)$

$$\rho = \frac{48.814}{T} + \frac{19.533}{T^2} \text{ (perfect gas + correction term)}$$

$$\mu = 0.36932\ T^{.69879} \text{ (power law [9])}$$

$$\kappa = -7.7800 \times 10^{-3} + 8.8343 \times 10^{-4}\ T - 1.6552 \times 10^{-6}\ T^2 + 1.5443 \times 10^{-9}\ T^3$$

$$C_p = \frac{5}{2}\frac{R}{M} = 5193.1 \text{ (monatomic gas, translational energy only)}$$

$$\alpha = -2.6439 \times 10^{-5} + 4.0054 \times 10^{-7}\ T + 9.3348 \times 10^{-10}\ T^2$$

$$\frac{\rho}{\mu} = 1.3093 \times 10^{8}\ T^{-1.6974}$$

$$\frac{g\beta}{\nu\alpha} = [4.4237 \times 10^{-2} - 7.3948 \times 10^{-4}\ T + 1.1041 \times 10^{-5}\ T^2]^{-2}$$

NITROGEN

TEMPERATURE RANGE: 200 - 400 K

PROPERTY	SOURCE	AVG. DEV (%)	MAX. DEV (%)	UNITS
ρ	Hilsenrath (1955)	0.013	0.030 @ 200 K	kg/m^3
μ	Touloukian (1970)	0.042	0.105 @ 200 K	$10^{-6}(N \cdot s)/m^2$
κ	Touloukian (1970)	0.091	0.173 @ 320 K	$W/(m \cdot K)$
C_p	Hilsenrath (1955)	0.006	0.015 @ 400 K	$J/(kg \cdot K)$
α	calc	0.067	0.115 @ 320 K	m^2/s
ρ/μ	calc	0.028	0.065 @ 200 K	s/m^2
$g\beta/\nu\alpha$	calc	0.140	0.255 @ 320 K	$10^6/(m^3 \cdot K)$

$$\rho = \frac{340.47}{T} + \frac{314.25}{T^2} \text{ (perfect gas + correction term)}$$

$$\mu = \frac{1.4153\ T^{3/2}}{111.61 + T} \text{ (Sutherland's equation [Reid (1966)])}$$

$$\kappa = -6.5326 \times 10^{-4} + 1.0606 \times 10^{-4}\ T - 5.7830 \times 10^{-8}\ T^2$$

$$C_p = 1063.6 - 0.15783\ T + 2.7622 \times 10^{-4}\ T^2$$

$$\alpha = 2.0410 \times 10^{-6} - 2.5939 \times 10^{-8}\ T + 3.8951 \times 10^{-10}\ T^2 - 2.7423 \times 10^{-13}\ T^3$$

$$\frac{\rho}{\mu} = \frac{2.7247 \times 10^{10}}{T^{5/2}} + \frac{2.4027 \times 10^{8}}{T^{3/2}}$$

$$\frac{g\beta}{\nu\alpha} = [-7.2947 \times 10^{-3} + 1.5042 \times 10^{-4}\ T - 1.5594 \times 10^{-6}\ T^2]^{-2}$$

WATER (SATURATED LIQUID)

TEMPERATURE RANGE: 280 - 370 K

PROPERTY	SOURCE	AVG. DEV (%)	MAX. DEV (%)	UNITS
ρ	Schmidt (1969)	0.038	0.072 @ 280 K	kg/m^3
μ	Kestin (1966)	—	—	$10^{-6}(N \cdot s)/m^2$
κ	Touloukian (1970)	—	—	$W/(m \cdot K)$
C_p	Touloukian (1970)	0.044	0.059 @ 280 K	$J/(kg \cdot K)$
α	calc	0.004	0.070 @ 280 K	$10^{-6}m^2/s$
ρ/μ	calc	0.004	0.070 @ 360 K	$10^6 s/m^2$
$g\beta/\nu\alpha$	calc	0.060	0.101 @ 290 K	$10^9/(m^3 \cdot K)$

$$\rho = 756.42 + 1.8595\, T - 3.5360 \times 10^{-3}\, T^2$$

$$\mu = 2.414 \times 10^{-5} \times 10^{247.8/(T-140.0)} \text{ (given in Kestin (1966))}$$

$$\kappa = -0.581798 + 6.35704 \times 10^{-3}\, T - 7.96625 \times 10^{-6}\, T^2$$

(given in Touloukian (1970))

$$C_p = 5631.3 - 9.2262\, T + 1.4622 \times 10^{-2}\, T^2$$

$$\alpha = -0.14400 + 1.5010 \times 10^{-3}\, T - 1.7795 \times 10^{-6}\, T^2$$

$$\frac{\rho}{\mu} = 19.785 - .20290\, T + 6.4639 \times 10^{-4}\, T^2 - 5.8979 \times 10^{-7}\, T^3$$

$$\frac{g\beta}{\nu\alpha} = 837.26 - 13.823\, T + 5.9344 \times 10^{-2}\, T^2 - 6.5571 \times 10^{-5}\, T^3$$

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