3 Physical and Chemical Data

PHYSICAL PROPERTIES OF GASES AND LIQUIDS

Name	Formula	Molecular Weight	Density g/L	Melting Point °C	Boiling Point °C	Auto-Ignition Point °C	Explosive Limits Percent by Vol. in Air Lower	Upper
Acetylene	C_2H_2	26.04	1.173	−81	−83.6 subl.	335	2.5	80.0
Air			1.2929					
Ammonia	NH_3	17.03	0.7710	−77.7	−33.4	780	16.0	27.0
Argon	Ar	39.94	1.784	−189.2	−185.7			
Butane-n	C_4H_{10}	58.12	0.601	−138	−0.6	430	1.6	8.5
Butane-i	C_4H_{10}	58.12	0.601	−159	−11.7			
Butylene-n	C_4H_8	56.10	0.595	−185	−6.3		1.7	9.0
Carbon dioxide	CO_2	44.01	1.977	−57 5 atm.	−78.5 subl.			
Carbon monoxide	CO	28.01	1.250	−207	−191	650	12.5	74.2
Chlorine	Cl_2	70.91	3.214	−101	−34			

Name	Formula	Molecular Weight	Density g/L	Melting Point ˚C	Boiling Point ˚C	Auto-Ignition Point ˚C	Explosive Limits Percent by Vol. in Air	
							Lower	Upper
Ethane	C_2H_6	30.07	0.572	−172	−88.6	510	3.1	15.0
Ethylene	C_2H_4	28.05	0.384	−169	−103.7	543	3.0	34.0
Helium	He	4.003	0.1785	−272	−268.9			
Heptane-n	C_7H_{16}	100.20	0.684 g/cm^3	−90.6	98.4	233	1.0	6.0
Hexane-n	C_6H_{14}	86.17	0.6594 g/cm^3	−95.3	68.7	248	1.2	6.9
Hydrogen	H_2	2.016	0.0899	−259.2	−252.8	580	4.1	74.2
Hydrogen chloride	HCl	36.47	1.639	−112	−84			
Hydrogen fluoride	HF	20.01	0.921	−92.3	19.5			
Hydrogen sulfide	H_2S	34.08	1.539	−84	−62		4.3	45.5
Methane	CH_4	16.04	0.7168	−182.5	−161.5	538	5.3	13.9
Nitrogen	N_2	28.016	1.2506	−209.9	−195.8			
Octane-n	C_8H_{18}	114.23	0.7025 g/cm^3	−56.8	125.7	232	0.8	3.2
Oxygen	O_2	32.00	1.4290	−218.4	−183.0			
Pentane-n	C_5H_{12}	72.15	0.625 g/cm^3	−131	36.2	310	1.4	8.0
Propane	C_3H_8	44.09	0.501	−189	−44.5	465	2.4	9.5
Propylene	C_3H_6	42.05	0.519	−184	−48	458	2.0	11.1
Sulfur dioxide	SO_2	64.06	2.926	−75.7	−10.0			

Density of gases in g/L at 0 ˚C and 760 mm Hg. Density of liquids in g/cm^3 at 4 ˚C (-7 ˚F).

PHYSICAL PROPERTIES OF ELEMENTS

	Symbol	Atomic Weight	Density g/cm³ 20˚C	Valencies	Melting Point ˚C	Crystal Structure ***
Aluminum	Al	26.98	2.70	3	660	1
Antimony	Sb	121.75	6.68	3/5	630	5
Argon	A	39.948	1.784*	0	−189.2	1
Arsenic	As	74.92	5.73	3/5	814	5
Barium	Ba	137.34	3.5	2	725	2
Beryllium	Be	9.01	1.85	2	1,280	3
Bismuth	Bi	208.98	9.80	3/5	271	5
Boron	B	10.81	2.3	3	2,300	-
Bromine	Br	79.91	3.12	1/3/5/7	−7.2	6
Cadmium	Cd	112.40	8.65	2	321	3
Calcium	Ca	40.08	1.55	2	842	1
Carbon	C	12.01	2.25	2/3/4	3,550	4
Chlorine	Cl	35.45	1.56**	1/3/5/7	−103	7
Chromium	Cr	52.00	7.2	2/3/6	1,890	2
Cobalt	Co	58.93	8.9	2/3	1,495	3
Copper	Cu	63.54	8.92	1/2	1,083	1
Fluorine	F	19.00	1.69*	1	223	-
Gold	Au	196.97	19.32	1/3	1,063	1
Helium	He	4.003	0.177*	0	−272.2	-
Hydrogen	H	1.008	0.090*	1	−259.2	4
Iodine	I	126.90	4.93	1/3/5/7	113.5	6
Iron	Fe	55.85	7.87	2/3/6	1,535	2
Lead	Pb	207.19	11.35	2/4	327.4	1
Lithium	Li	6.94	0.53	1	186	2
Magnesium	Mg	24.31	1.74	2	651	3
Manganese	Mn	54.94	7.2	2/3/4/6/7	1,260	10
Mercury	Hg	200.59	13.55	1/2	−38.9	5
Molybdenum	Mo	95.94	10.2	2/3/4/5/6	2,620	2
Nickel	Ni	58.71	8.90	2/3	1,455	1

	Symbol	Atomic Weight	Density g/cm³ 20˚C	Valencies	Melting Point ˚C	Crystal Structure ***
Niobium	Nb	92.91	8.55	3/5	2,500	2
Nitrogen	N	14.007	1.25*	3/5	−209.9	4
Oxygen	O	15.9994	1.429*	2	−218.4	10
Phosphorus	P	30.98	1.82	3/5	44.1	10
Platinum	Pt	195.09	21.37	2/4	1,773	1
Potassium	K	39.10	0.87	1	62.3	2
Rhodium	Rh	102.91	12.5	1/2/3/4	1,966	1
Selenium	Se	78.96	4.8	2/4/6	220	4
Silicon	Si	28.09	2.42	4	1,420	8
Silver	Ag	107.87	10.50	1	960.5	1
Sodium	Na	22.99	0.97	1	97.5	2
Sulfur	S	32.06	2.07	2/4/6	119	9
Tantalum	Ta	180.95	16.6	3/5	2,996	2
Tin	Sn	118.69	7.31	2/4	231.9	7
Titanium	Ti	47.90	4.5	2/3/4	1,800	3
Tungsten	W	183.85	19.3	2/4/5/6	3,370	2
Vandium	V	50.94	5.96	2/3/4/5	1,710	2
Zinc	Zn	65.73	7.14	2	419.5	3
Zirconium	Zr	91.22	6.4	4	1,857	3

*g/L (0 ˚C and 760 mm Hg)

**Liquid at boiling point −37 ˚C

***at 20 ˚C

Crystal structures:

1. Face-centered cubic
2. Body-centered cubic
3. Close packed hexagonal
4. Hexagonal
5. Rhombohedral
6. Orthorhombic
7. Tetragonal
8. Diamond cubic
9. Face-centered orthorhombic
10. Cubic (complex)

PROCESSES FOR REAGENT WATER PRODUCTION

Type	Grade	Production Process [A,B,C,D]	µS/cm[E] (max)	MΩ-cm[F] (min)	pH[G]	TOC µg/L[H] (max)	Sodium µg/L[I] (max)	Chloride µg/L[J] (max)	Total Silica µg/L (max)	HBC[K] cfu/mL (max)	Endo-toxin EU/mL[L] (max)
I		Purify to 20 µS/com by dist. or equiv., followed by mixed bed DI, 0.2µm filtration[A]	0.0555	18		50	1	1	3		
I	A	Purify to 20 µS/com by dist. or equiv., followed by mixed bed DI, 0.2µm filtration[A]	0.0555	18		50	1	1	3	10/1000	0.03
I	B	Purify to 20 µS/com by dist. or equiv., followed by mixed bed DI, 0.2µm filtration[A]	0.0555	18		50	1	1	3	10/100	0.25
I	C	Purify to 20 µS/com by dist. or equiv., followed by mixed bed DI, 0.2µm filtration[A]	0.0555	18		50	1	1	3	100/10	
II		Distillation[B]	1.0	1.0		50	5	5	3		
II	A	Distillation[B]	1.0	1.0		50	5	5	3	10/1000	0.03
II	B	Distillation[B]	1.0	1.0		50	5	5	3	10/100	0.25
II	C	Distillation[B]	1.0	1.0		50	5	5	3	100/10	
III		Distillation, DI, EDI, and/or RO, followed by 0.45 µm filtration.[C]	0.25	4.0		200	10	10	500		
III	A	Distillation, DI, EDI, and/or RO, followed by 0.45 µm filtration.[C]	0.25	4.0		200	10	10	500	10/1000	0.03
III	B	Distillation, DI, EDI, and/or RO, followed by 0.45 µm filtration.[C]	0.25	4.0		200	10	10	500	10/100	0.25
III	C	Distillation, DI, EDI, and/or RO, followed by 0.45 µm filtration.[C]	0.25	4.0		200	10	10	500	1000/100	
IV		Distillation, DI, EDI, and/or RO.[D]	5.0	0.2	5.0 to 8.0		50	50			
IV	A	Distillation, DI, EDI, and/or RO.[D]	5.0	0.2	5.0 to 8.0		50	50		10/1000	0.03
IV	B	Distillation, DI, EDI, and/or RO.[D]	5.0	0.2	5.0 to 8.0		50	50		10/100	0.25
IV	C	Distillation, DI, EDI, and/or RO.[D]	5.0	0.2	5.0 to 8.0		50	50		100/10	

[A] Type I grade of reagent water shall be prepared by distillation or other equal process, followed by polishing with a mixed bed of ion-exchange materials and a 0.2-µm membrane filter. Feed water to the final polishing step must have a maximum conductivity of 20 µS/cm at 298 K (25 °C). Type I reagent water may be produced with alternate technologies as long as the appropriate constituent specifications are met and that water so produced has been shown to be appropriate for the application where the use of such water is specified.

[B] Type II grade of reagent water shall be prepared by distillation using a still designed to produce a distillate having a conductivity of less than 1.0 µS/cm at 298 K (25 °C). Ion exchange, distillation, or reverse osmosis and organic adsorption may be required prior to distillation, if the purity cannot be attained by single distillation. Type II reagent water may be produced with alternate technologies as long as the appropriate constituent specifications are met and that water so produced has been shown to be appropriate for the application where the use of such water is specified.

[C] Type Ill grade of reagent water shall be prepared by distillation, ion exchange, continuous electrodeionization, reverse osmosis, or a combination thereof, followed by polishing with a 0.45-µm membrane filter. Type Ill reagent water may be produced with alternate technologies as long as the appropriate constituent specifications are met and that water so produced has been shown to be appropriate for the application where the use of such water is specified.

[D] Type IV grade of reagent water may be prepared by distillation, ion exchange, continuous electrodeionization, reverse osmosis, electrodialysis, or a combination thereof. Type IV reagent water may be produced with alternate technologies as long as the appropriate constituent specifications are met and that water so produced has been shown to be appropriate for the application where the use of such water is specified.

[E] Electrical conductivity at 25 °C.

[F] Electrical resistivity at 25 °C.

[G] pH at 25 °C, not applicable to higher resistivity waters.

[H] Total organic carbon.

[I] Sodium.

[J] Chloride ion.

[K] Heterotrophic bacteria count.

[L] Endotoxin in endotoxin units per ml.

Source: ASTM D1193-06, "Standard Specification for Reagent Water" ((West Conshohocken, PA, USA: ASTM International, 2006). Reprinted with permission, copyright ASTM International.

PHYSICAL PROPERTIES OF WATER

Temperature	Density[1]	Specific Volume[2]	Vapor Pressure[2]	Viscosity[3]	Dielectric Constant[4]
t °C	*d* g/ml	*v* ml/g	*p* mm Hg*	η centipose	*E*
0**	0.99987	1.00013	4.580	1.787	87.74
5	.99999	1.00001	6.538	1.517	85.76
10	.99973	1.00027	9.203	1.306	83.83
15	.99913	1.00087	12.782	1.138	81.95
18	.99862	1.00138	15.471	1.053	80.84
20	.99823	1.00177	17.529	1.002	80.10
25	.99707	1.00293	23.753	0.8903	78.30
30	.99567	1.00434	31.824	.7974	76.55
35	.99406	1.00598	42.180	.7194	74.83
38	.99299	1.00706	49.702	.6783	73.82
40	.99224	1.00782	55.338	.6531	73.15
45	.99025	1.00985	71.90	.5963	71.51
50	.98807	1.01207	92.56	.5471	69.91
55	.98573	1.01448	118.11	.5044	68.34
60	.98324	1.01705	149.47	.4669	66.81
65	.98059	1.01979	187.65	.4338	65.32
70	.97781	1.02270	233.81	.4044	63.86
75	.97489	1.02576	289.22	.3782	62.43
80	.97183	1.02899	355.31	.3547	61.03
85	.96865	1.03237	433.64	.3340	59.66
90	.96534	1.03590	525.92	.3149	58.32
95	.96192	1.03959	634.04	.2976	57.01
100***	.95838	1.04343	760.00	.2822	55.72

(1) M. Thiesen, Wiss. Abh. der Physikalisch-Technischen Reichsanstalt 4, No. 1, 1904; International Critical Tables 3, 25 (1928).
(2) F. G. Keyes, J. Chem. Phys., 15, 602 (1947).
(3) J. F. Swindells, J. R. Coe, and T. B. Godfrey, J. Research Nat. Bur. Standards, 48, 1 (1952); R. C. Hardy and R. L. Cottington, *ibid*, 42, 573 (1949); J. R. Coe and T. B. Godfrey, J. App. Phys., 15, 625 (1944).

(4) C. G. Malmberg and A. A. Maryott, J. Research Nat. Bur. Standards, 56, 1 (1956).
* 760 mm Hg = 1 atmosphere = 1,013,250 dyn cm−2 = 101,325 newtons m−2 ; on the Syste` me International d'Unites, adopted in a resolution, 11th General Conference on Weights and Measures, Paris, October 1960, the international unit of pressure is the newton per square meter.
**The freezing point is zero degrees Celsius, exactly; the triple point of water is 0.001 ◦ C or 273.16 K.
***The boiling point.

PROPERTIES OF DRY SATURATED STEAM (English Units)

Temp. ˚F	Pressure psia	Pressure psig	Specific Volume ft.^{3}/lb.	Specific Enthaipy Btu/lb.
32	0.08859	-	3,305	1,075.5
35	0.09991	-	2,948	1,076.8
40	0.12163	-	2,446	1,079.0
45	0.14744	-	2,037.8	1,081.2
50	0.17796	-	1,704.8	1,083.4
60	0.2561	-	1,207.6	1,087.7
70	0.3629	-	868.4	1,092.1
80	0.5068	-	633.3	1,096.4
90	0.6981	-	468.1	1,100.8
100	0.9492	-	350.4	1,105.1
110	1.2750	-	265.4	1,109.3
120	1.6927	-	203.26	1,113.6
130	2.2230	-	157.33	1,117.8
140	2.8892	-	123.00	1,122.0
150	3.718	-	97.07	1,126.1
160	4.741	-	77.29	1,130.2
170	5.993	-	62.06	1,134.2
180	7.511	-	50.22	1,138.2
190	9.340	-	40.96	1,142.1
200	11.526	-	33.64	1,146.0
210	14.123	-	27.82	1,149.7
212	14.696	0.000	26.80	1,150.5

Temp. °F	Pressure psia	Pressure psig	Specific Volume ft.^{3}/lb.	Specific Enthaipy Btu/lb.
220	17.186	2.490	23.15	1,153.4
230	20.779	6.083	19.381	1,157.1
240	24.968	10.272	16.321	1,160.6
250	29.825	15.129	13.819	1,164.0
260	35.427	20.731	11.762	1,167.4
270	41.856	27.160	10.060	1,170.6
280	49.200	34.524	8.644	1,173.8
290	57.550	42.854	7.460	1,176.8
300	67.005	52.309	6.466	1,179.7
310	77.67	62.97	5.626	1,182.5
320	89.64	74.94	4.914	1,185.2
340	117.99	103.29	3.788	1,190.1
360	153.01	138.31	2.957	1,194.4
380	195.73	181.03	2.335	1,198.0
400	247.26	232.56	1.8630	1,201.0
420	308.78	294.08	1.4997	1,203.1
440	381.54	366.84	1.2169	1,204.4
460	466.9	452.2	0.9942	1,204.8
480	566.2	551.5	0.8172	1,204.1
500	680.9	666.2	0.6749	1,202.2
520	812.5	797.8	0.5596	1,199.0
540	962.8	948.1	0.4651	1,194.3
560	1,133.4	1,118.7	0.3871	1,187.7
580	1,326.2	1,311.5	0.3222	1,179.0
600	1,543.2	1,528.5	0.2675	1,167.7
620	1,786.9	1,772.2	0.2208	1,153.2
640	2,059.9	2,045.2	0.1802	1,133.7
660	2,365.7	2,351.0	0.1443	1,107.0
680	2,708.6	2,693.9	0.1112	1,068.5
700	3,094.3	3,079.6	0.0752	995.2
705.5	3,208.2	3,193.5	0.0508	906.0

Source: G.L. Tomei, ed., *Steam* (Babcock and Wilcox) pp. 2–3. Reprinted with permission from ASME International.

PROPERTIES OF DRY SATURATED STEAM (SI UNITS)

Abs. Pressure bar	Temp. ˚C	Specific Volume dm^3/kg	Specific Enthalpy kJ/kg
0.01	7.0	129,209	2,514
0.025	21.1	54,256	2,540
0.05	32.9	28,194	2,562
0.075	40.3	19,239	2,575
0.10	45.8	14,675	2,585
0.15	54.0	10,023	2,599
0.20	60.1	7,650	2,610
0.25	65.0	6,205	2,618
0.30	69.1	5,229	2,625
0.40	75.9	3,993	2,637
0.50	81.3	3,240	2,646
0.75	91.8	2,217	2,663
1.0	99.6	1,694	2,675
1.5	111.4	1,159	2,693
2.0	120.2	885	2,706
2.5	127.4	718	2,716
3.0	133.5	606	2,725
3.5	138.9	524	2,732
4.0	143.6	462	2,738
5.0	151.8	375	2,748
6.0	158.8	315	2,756
7.0	164.9	273	2,762
8.0	170.4	240	2,768
9.0	175.4	215	2,772
10.0	179.9	194.3	2,776
12.5	189.8	156.9	2,784
15.0	198.3	131.7	2,790
17.5	205.7	113.4	2,794
20.0	212.4	99.5	2,797

Abs. Pressure bar	Temp. ˚C	Specific Volume dm^3/kg	Specific Enthalpy kJ/kg
22.5	218.4	88.7	2,799
25.0	223.9	79.9	2,801
27.5	229.0	72.7	2,802
30.0	233.8	66.6	2,802
32.5	238.3	61.5	2,802
35.0	242.5	57.0	2,802
37.5	246.5	53.2	2,801
40.0	250.3	49.7	2,800
45.0	257.4	44.0	2,798
50.0	263.9	39.4	2,794
55.0	269.9	35.6	2,790
60.0	275.6	32.4	2,785
65.0	280.8	29.7	2,780
70.0	285.8	27.4	2,774
75.0	290.5	25.3	2,767
80.0	295.0	23.5	2,760
85.0	299.2	21.9	2,753
90.0	303.2	20.5	2,745
95.0	307.2	19.21	2,736
100.0	311.0	18.04	2,728
110.0	318.0	16.01	2,709
120.0	324.6	14.28	2,689
130.0	330.8	12.80	2,667
140.0	336.6	11.50	2,642
150.0	342.1	10.34	2,615
160.0	347.3	9.31	2,585
170.0	352.3	8.37	2,552
180.0	357.0	7.50	2,514
190.0	361.4	6.68	2,471
200.0	365.7	5.88	2,418
210.0	369.8	5.02	2,348
220.0	373.7	3.73	2,196

Abs. Pressure bar	Temp. °C	Specific Volume dm^3/kg	Specific Enthalpy kJ/kg
221.2	374.2	3.17	2,107
60.0	275.6	32.4	2,785
60.0	275.6	32.4	2,785
65.0	280.8	29.7	2,780
70.0	285.8	27.4	2,774
75.0	290.5	25.3	2,767
80.0	295.0	23.5	2,760
85.0	299.2	21.9	2,753
90.0	303.2	20.5	2,745
95.0	307.2	19.21	2,736
100.0	311.0	18.04	2,728
110.0	318.0	16.01	2,709
120.0	324.6	14.28	2,689
130.0	330.8	12.80	2,667
140.0	336.6	11.50	2,642
150.0	342.1	10.34	2,615
160.0	347.3	9.31	2,585
170.0	352.3	8.37	2,552
180.0	357.0	7.50	2,514
190.0	361.4	6.68	2,471
200.0	365.7	5.88	2,418
210.0	369.8	5.02	2,348
220.0	373.7	3.73	2,196
221.2	374.2	3.17	2,107

Source: A. Parrish, *Mechanical Engineer's Reference Book* (Oxford, UK: Butterworth-Heinemann, 1973), pp. 2-86, 2-93. Reprinted with permission from ASME International.

VAPOR PRESSURE OF WATER BELOW 100 ˚C

Temperature		Pressure		Temperature		Pressure	
˚C	˚F	mm	Hg	˚C	˚F	mm	Hg
−15	5	1.4	1.9	43	109	64.8	86.4
−14	7	1.6	2.1	44	111	68.3	91.0
−13	9	1.7	2.3	45	113	71.9	95.8
−12	10	1.8	2.4	46	115	75.7	101
−11	12	2.0	2.7	47	117	79.6	106
−10	14	2.1	2.8	48	118	83.7	112
−9	16	2.3	3.1	49	120	88.0	117
−8	18	2.5	3.3	50	122	92.5	123
−7	19	2.7	3.6	51	124	97.2	130
−6	21	2.9	3.9	52	126	102.1	136
−5	23	3.2	4.3	53	127	107.2	143
−4	25	3.4	4.5	54	129	112.5	151
−3	27	3.7	4.9	55	131	118.0	157
−2	28	4.0	5.3	56	133	123.8	165
−1	30	4.3	5.7	57	135	129.8	173
0	32	4.6	6.1	58	136	136.1	181
1	34	4.9	6.5	59	138	142.6	191
2	36	5.3	7.1	60	140	149.4	199
3	37	5.7	7.6	61	142	156.4	208
4	39	6.1	8.1	62	144	163.8	219
5	41	6.5	8.7	63	145	171.4	228
6	43	7.0	9.3	64	147	179.3	239
7	45	7.5	10.0	65	149	187.5	249
8	46	8.0	10.7	66	151	196.1	261
9	48	8.6	11.5	67	153	205.0	273
10	50	9.2	12.3	68	154	214.2	285
11	52	9.8	13.1	69	156	223.7	299
12	54	10.5	14.0	70	158	233.7	312
13	55	11.2	14.9	71	160	243.9	325

Temperature		Pressure		Temperature		Pressure	
°C	°F	mm	Hg	°C	°F	mm	Hg
14	57	12.0	16.0	72	162	254.6	340
15	59	12.8	17.1	73	163	265.7	355
16	61	13.6	18.1	74	165	277.2	369
17	63	14.5	19.3	75	167	289.1	385
18	64	15.5	20.7	76	169	301.4	401
19	66	16.5	22.0	77	171	314.1	419
20	68	17.5	23.3	78	172	327.3	436
21	70	18.6	24.8	79	174	341.0	455
22	72	19.8	26.4	80	176	355.1	473
23	73	21.1	28.1	81	178	369.7	493
24	75	22.4	29.9	82	180	384.9	513
25	77	23.8	31.7	83	181	400.6	535
26	79	25.2	33.6	84	183	416.8	556
27	81	26.7	35.6	85	185	433.6	579
28	82	28.3	37.7	86	187	450.9	601
29	84	30.0	40.0	87	189	468.7	625
30	86	31.8	42.4	88	190	487.1	649
31	88	33.7	44.9	89	192	506.1	674
32	90	35.7	47.6	90	194	525.8	701
33	91	37.7	50.3	91	196	546.0	728
34	93	39.9	53.2	92	198	567.0	756
35	95	42.2	56.3	93	199	588.6	785
36	97	44.6	59.5	94	201	610.9	822
37	99	47.1	62.8	95	203	633.9	845
38	100	49.7	66.3	96	205	657.6	877
39	102	52.4	69.8	97	207	682.1	909
40	104	55.3	73.7	98	208	707.3	942
41	106	58.3	77.7	99	210	733.2	977
42	108	61.5	81.2	100	212	760.0	1,013

Source: R.C. Weast, ed., *CRC Handbook*, 55th ed. (Boca Raton, Florida, USA: CRC Press, 1974), p. D-159. Reprinted with permission, copyright CRC Press.

DEW POINT OF MOIST AIR

The temperature drop required for condensation to occur at a specified air temperature and relative humidity is given in the table below. The temperature drops are mean values for the indicated air temperature ranges.

Air Temperature ˚C			Air Temperature ˚F		
RH%	0–20	20–35	RH%	32–68	68–95
55	9	10	55	16	18
60	7	9	60	13	15
65	6	7	65	11	13
70	5	6	70	9	11
75	4	5	75	8	9
80	3	4	80	6	7
85	2	3	85	4	5
90	1.6	1.8	90	3	3
92	1.2	1.4	92	2.2	2.5
95	0.8	0.9	95	1.4	1.6
98	0.3	0.3	98	0.5	0.5

Example: At 30 ˚C (86 ˚F) and 80% RH, a temperature drop of 4 ˚C (7 ˚F) would result in condensation.

Dew point temperatures of moist air as a function of air temperature and relative humidity are tabulated on the following four pages.

DEW POINT OF MOIST AIR (˚C)

Air Temperature˚C

RH%	0	2	4	6	8	10	12	14	16	18	20	22	24
1	−50	−49	−47	−46	−45	−44	−42	−41	−40	−39	−38	−36	−35
3	−40	−39	−37	−36	−34	−33	−32	−30	−29	−28	−26	−25	−24
5	−35	−34	−32	−31	−29	−28	−26	−25	−24	−22	−21	−19	−18
7	−32	−30	−29	−27	−26	−24	−23	−21	−20	−18	−17	−15	−14
9	−29	−27	−26	−24	−23	−21	−20	−18	−17	−15	−14	−12	−11
11	−27	−25	−24	−22	−21	−19	−17	−16	−14	−13	−11	−10	−8
13	−25	−23	−22	−20	−19	−17	−15	−14	−12	−11	−9	−8	−6
15	−23	−22	−20	−19	−17	−15	−14	−12	−11	−9	−7	−6	−4
17	−22	−20	−19	−17	−15	−14	−12	−11	−9	−7	−6	−4	−2
19	−21	−19	−17	−16	−14	−12	−11	−9	−8	−6	−4	−3	−1
21	−20	−18	−16	−15	−13	−11	−10	−8	−6	−5	−3	−1	0
23	−19	−17	−15	−14	−12	−10	−8	−7	−5	−3	−2	0	2
25	−18	−16	−14	−13	−11	−9	−7	−6	−4	−2	−1	1	3
27	−17	−15	−13	−12	−10	−8	−6	−5	−3	−1	1	2	4
29	−16	−14	−12	−11	−9	−7	−5	−4	−2	0	2	3	5
31	−15	−13	−12	−10	−8	−6	−5	−3	−1	1	2	4	6
33	−14	−13	−11	−9	−7	−6	−4	−2	0	2	3	5	7
35	−14	−12	−10	−8	−7	−5	−3	−1	1	2	4	6	8
37	−13	−11	−9	−8	−6	−4	−2	0	1	3	5	7	9
39	−12	−10	−9	−7	−5	−3	−1	0	2	4	6	8	9
41	−12	−10	−8	−6	−4	−3	−1	1	3	5	6	8	10
43	−11	−9	−7	−6	−4	−2	0	2	4	5	7	9	11
45	−11	−9	−7	−5	−3	−1	1	2	4	6	8	10	11
47	−10	−8	−6	−5	−3	−1	1	3	5	7	8	10	12

RH%	0	2	4	6	8	10	12	14	16	18	20	22	24
49	−9	−8	−6	−4	−2	0	2	4	5	7	9	11	13
51	−9	−7	−5	−3	−1	0	2	4	6	8	10	12	13
53	−8	−7	−5	−3	−1	1	3	5	7	8	10	12	14
55	−8	−6	−4	−2	−1	1	3	5	7	9	11	13	14
57	−7	−6	−4	−2	0	2	4	6	8	9	11	13	15
59	−7	−5	−3	−1	1	2	4	6	8	10	12	14	16
61	−7	−5	−3	−1	1	3	5	7	9	11	12	14	16
63	−6	−4	−2	0	2	3	5	7	9	11	13	15	17
65	−6	−4	−2	0	2	4	6	8	10	11	13	15	17
67	−5	−3	−2	0	2	4	6	8	10	12	14	16	18
69	−5	−3	−1	1	3	5	7	8	10	12	14	16	18
71	−5	−3	−1	1	3	5	7	9	11	13	15	17	19
73	−4	−2	0	2	4	6	7	9	11	13	15	17	19
75	−4	−2	0	2	4	6	8	10	12	14	15	17	19
77	−4	−2	0	2	4	6	8	10	12	14	16	18	20
79	−3	−1	1	3	5	7	8	10	12	14	16	18	20
81	−3	−1	1	3	5	7	9	11	13	15	17	19	21
83	−3	−1	1	3	5	7	9	11	13	15	17	19	21
85	−2	0	2	4	6	8	10	12	14	16	18	19	21
87	−2	0	2	4	6	8	10	12	14	16	18	20	22
89	−2	0	2	4	6	8	10	12	14	16	18	20	22
91	−1	1	3	5	7	9	11	13	15	17	19	21	23
93	−1	1	3	5	7	9	11	13	15	17	19	21	23
95	−1	1	3	5	7	9	11	13	15	17	19	21	23
97	0	2	4	6	8	10	12	14	16	18	20	22	24
99	0	2	4	6	8	10	12	14	16	18	20	22	24

RH%	26	28	30	32	34	36	38	40	42	44	46	48	50
1	−34	−33	−32	−30	−29	−28	−27	−26	−25	−24	−22	−21	−20
3	−22	−21	−20	−18	−17	−16	−14	−13	−12	−11	−9	−8	−7
5	−16	−15	−14	−12	−11	−10	−8	−7	−5	−4	−3	−1	0
7	−12	−11	−9	−8	−7	−5	−4	−2	−1	1	2	4	5
9	−9	−8	−6	−5	−3	−2	0	1	3	4	6	7	9
11	−7	−5	−4	−2	−1	1	3	4	6	7	9	10	12
13	−4	−3	−1	0	2	3	5	6	8	10	11	13	14
15	−3	−1	1	2	4	5	7	9	10	12	13	15	16
17	−1	1	2	4	6	7	9	10	12	14	15	17	18
19	1	2	4	6	7	9	10	12	14	15	17	19	20
21	2	4	5	7	9	10	12	14	15	17	19	20	22
23	3	5	7	8	10	12	13	15	17	18	20	22	23
25	5	6	8	10	11	13	15	16	18	20	21	23	25
27	6	7	9	11	12	14	16	18	19	21	23	24	26
29	7	8	10	12	14	15	17	19	20	22	24	25	27
31	8	9	11	13	15	16	18	20	21	23	25	27	28
33	9	10	12	14	16	17	19	21	22	24	26	28	29
35	9	11	13	15	16	18	20	22	23	25	27	29	30
37	10	12	14	16	17	19	21	23	24	26	28	30	31
39	11	13	15	16	18	20	22	24	25	27	29	31	32
41	12	14	15	17	19	21	23	24	26	28	30	31	33
43	13	14	16	18	20	22	23	25	27	29	31	32	34
45	13	15	17	19	20	22	24	26	28	29	31	33	35
47	14	16	17	19	21	23	25	27	28	30	32	34	36
49	15	16	18	20	22	24	26	27	29	31	33	35	36
51	15	17	19	21	23	24	26	28	30	32	34	35	37
53	16	18	20	21	23	25	27	29	31	32	34	36	38
55	16	18	20	22	24	26	27	29	31	33	35	37	38
57	17	19	21	23	24	26	28	30	32	34	36	37	39
59	17	19	21	23	25	27	29	30	32	34	36	38	40
61	18	20	22	24	26	27	29	31	33	35	37	39	41
63	19	20	22	24	26	28	30	32	34	35	37	39	41
65	19	21	23	25	27	28	30	32	34	36	38	40	42

RH%	26	28	30	32	34	36	38	40	42	44	46	48	50
67	19	21	23	25	27	29	31	33	35	37	38	40	42
69	20	22	24	26	28	30	31	33	35	37	39	41	43
71	20	22	24	26	28	30	32	34	36	38	40	42	43
73	21	23	25	27	29	31	32	34	36	38	40	42	44
75	21	23	25	27	29	31	33	35	37	39	41	42	44
77	22	24	26	28	29	31	33	35	37	39	41	43	45
79	22	24	26	28	30	32	34	36	38	40	41	43	45
81	23	25	26	28	30	32	34	36	38	40	42	44	46
83	23	25	27	29	31	33	35	37	39	40	42	44	46
85	23	25	27	29	31	33	35	37	39	41	43	45	47
87	24	26	28	30	32	34	36	37	39	41	43	45	47
89	24	26	28	30	32	34	36	38	40	42	44	46	48
91	25	27	29	31	32	34	36	38	40	42	44	46	48
93	25	27	29	31	33	35	37	39	41	43	45	47	49
95	25	27	29	31	33	35	37	39	41	43	45	47	49
97	26	28	30	32	34	36	38	40	42	44	46	48	50
99	26	28	30	32	34	36	38	40	42	44	46	48	50

DEW POINT OF MOIST AIR (˚F)

Air Temperature˚F

RH%	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74
1	−57	−56	−54	−52	−50	−48	−46	−45	−43	−41	−39	−37	−36	−34	−32
3	−40	−38	−36	−34	−32	−30	−28	−25	−23	−21	−19	−17	−15	−13	−11
5	−31	−29	−27	−25	−22	−20	−18	−16	−14	−12	−9	−7	−5	−3	−1
7	−25	−23	−20	−18	−16	−14	−11	−9	−7	−5	−2	0	2	4	6
9	−20	−18	−15	−13	−11	−9	−6	−4	−2	1	3	5	7	10	12
11	−16	−14	−12	−9	−7	−5	−2	0	2	5	7	9	12	14	16
13	−13	−11	−8	−6	−3	−1	1	4	6	8	11	13	16	18	20
15	−10	−8	−5	−3	0	2	4	7	9	12	14	16	19	21	24
17	−8	−5	−3	0	2	5	7	10	12	15	17	19	22	24	27
19	−5	−3	0	2	5	7	10	12	15	17	19	22	24	27	29
21	−3	−1	2	4	7	9	12	14	17	19	22	24	27	29	32
23	−1	1	4	6	9	11	14	16	19	21	24	26	29	31	34
25	0	3	5	8	11	13	16	18	21	23	26	28	31	33	36
27	2	5	7	10	12	15	17	20	23	25	28	30	33	35	38

RH%	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74
29	4	6	9	11	14	17	19	22	24	27	29	32	35	37	40
31	5	8	10	13	16	18	21	23	26	29	31	34	36	39	42
33	6	9	12	14	17	20	22	25	27	30	33	35	38	41	43
35	8	10	13	16	18	21	24	26	29	31	34	37	39	42	45
37	9	12	14	17	20	22	25	28	30	33	36	38	41	44	46
39	10	13	15	18	21	23	26	29	32	34	37	40	42	45	48
41	11	14	17	19	22	25	27	30	33	35	38	41	44	46	49
43	12	15	18	20	23	26	29	31	34	37	39	42	45	48	50
45	13	16	19	21	24	27	29	32	35	38	40	43	46	49	51
47	14	17	20	22	25	28	31	33	36	39	42	44	47	50	52
49	15	18	21	24	26	29	32	35	37	40	43	46	48	51	54
51	16	19	22	24	27	30	33	36	38	41	44	47	49	52	55
53	17	20	23	25	28	31	34	37	39	42	45	48	50	53	56
55	18	21	23	26	29	32	35	37	40	43	46	48	51	54	57
57	19	21	24	27	30	33	35	38	41	44	47	50	52	55	58
59	19	22	25	28	31	33	36	39	42	45	48	50	53	56	59
61	20	23	26	29	32	34	37	40	43	46	49	51	54	57	60
63	21	24	27	29	32	35	38	41	44	47	49	52	55	58	61
65	22	25	27	30	33	36	39	42	44	47	50	53	56	59	62
67	22	25	28	31	34	37	40	42	45	48	51	54	57	60	62
69	23	26	29	32	35	37	40	43	46	49	52	55	58	60	63
71	24	27	30	32	35	38	41	44	47	50	53	55	58	61	64
73	24	27	30	33	36	39	42	45	48	51	53	56	59	62	65
75	25	28	31	34	37	39	42	45	48	51	54	57	60	63	66
77	26	29	32	34	37	40	43	46	49	52	55	58	61	64	66
79	26	29	32	35	38	41	44	47	50	52	55	58	61	64	67
81	27	30	33	36	39	42	44	47	50	53	56	59	62	65	68
83	27	30	33	36	39	42	45	48	51	54	57	60	63	66	68
85	28	31	34	37	40	43	46	49	52	55	58	60	64	66	69
87	29	32	34	37	40	43	46	49	52	55	58	61	64	67	70
89	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71
91	30	33	36	39	42	45	48	51	54	56	60	62	65	68	71
93	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72
95	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73
97	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73
99	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74

RH%	77	80	83	86	89	92	95	98	101	104	107	110	113	116	119	122
1	−30	−28	27	−25	−23	−21	−20	−18	−16	−14	−13	−11	−9	−7	−6	−4
3	−9	−7	−5	−3	−1	1	2	4	6	8	10	12	14	16	18	20
5	1	3	5	8	10	12	14	16	18	20	22	24	26	28	30	32
7	8	11	13	15	17	19	22	24	26	28	30	32	35	37	39	41
9	14	16	19	21	23	25	28	30	32	34	36	39	41	43	45	47
11	19	21	23	26	28	30	32	35	37	39	41	44	46	48	50	53
13	23	25	27	30	32	34	37	39	41	44	46	48	51	53	55	57
15	26	28	31	33	35	38	40	43	45	47	50	52	54	57	59	61
17	29	31	34	36	39	41	44	46	48	51	53	55	58	60	63	65
19	32	34	37	39	42	44	46	49	51	54	56	59	61	63	66	68
21	34	37	39	42	44	47	49	52	54	56	59	61	64	66	69	71
23	37	39	42	44	47	49	51	54	56	59	61	64	66	69	71	74
25	38	41	44	46	49	51	54	56	59	61	64	66	69	71	74	76
27	41	43	46	48	51	53	56	58	61	64	66	68	71	74	76	79
29	42	45	48	50	53	55	58	60	63	65	68	71	73	76	78	81
31	44	47	49	52	55	57	60	62	65	67	70	73	75	78	80	83
33	46	48	51	54	56	59	61	64	67	69	72	74	77	80	82	85
35	47	50	53	55	58	60	63	66	68	71	74	76	79	81	84	87
37	49	52	54	57	60	62	65	67	70	73	75	78	81	83	86	89
39	50	53	56	58	61	64	66	69	72	74	77	80	82	85	87	90
41	52	54	57	60	62	65	68	70	73	76	78	81	84	86	89	92
43	53	56	58	61	64	66	69	72	75	77	80	83	85	88	91	93
45	54	57	60	62	65	58	70	73	76	78	81	84	87	89	92	95
47	55	58	61	63	66	69	72	74	77	80	82	85	88	91	93	96
49	56	59	62	65	68	70	73	76	78	81	84	87	89	92	95	98
51	58	60	63	66	69	71	74	77	80	82	85	88	91	93	96	99
53	59	62	64	67	70	73	75	78	81	84	86	89	92	95	97	100
55	60	62	65	68	71	73	76	79	82	85	87	90	93	96	98	101
57	61	64	66	69	72	75	78	80	83	86	89	91	94	97	100	103
59	62	64	67	70	73	76	78	81	84	87	90	92	95	98	101	104
61	63	66	68	71	74	77	80	82	85	88	91	94	96	99	102	105
63	64	66	69	72	75	78	81	83	86	89	92	95	98	100	103	106
65	64	67	70	73	76	79	82	84	87	90	93	96	98	101	104	107
67	65	68	71	74	77	80	82	85	88	91	94	97	100	102	105	108
69	66	69	72	75	78	80	83	86	89	92	95	98	100	103	106	109
71	67	70	73	76	79	81	84	87	90	93	96	99	101	104	107	110

RH%	77	80	83	86	89	92	95	98	101	104	107	110	113	116	119	122
73	68	71	74	76	79	82	85	88	91	94	97	100	102	105	108	111
75	69	71	74	77	80	83	86	89	92	94	97	100	103	106	109	112
77	69	72	75	78	81	84	87	90	93	96	98	101	104	107	110	113
79	70	73	76	79	82	84	87	90	93	96	99	102	105	108	111	114
81	71	74	77	80	82	85	88	91	94	97	100	103	106	109	112	115
83	71	74	77	80	83	86	89	92	95	98	101	104	107	109	112	115
85	72	75	78	81	84	87	90	93	96	99	102	105	108	110	113	116
87	73	76	79	82	85	88	91	94	96	99	102	105	108	111	114	117
89	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115	118
91	74	77	80	83	86	89	92	95	98	101	104	107	110	113	116	119
93	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	120
95	76	79	82	85	87	90	93	96	99	102	105	108	111	114	117	120
97	76	79	82	85	88	91	94	97	100	103	106	109	112	115	118	121
99	77	80	83	86	89	92	95	98	101	104	107	110	113	116	119	122

PERCENT RELATIVE HUMIDITY ABOVE WHICH MOISTURE WILL CONDENSE ON METAL SURFACES NOT INSULATED

Surrounding Air Temperature ˚F

Metal Surface Temp.	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
35 ˚F	60	33	11														
40		69	39	20	8												
45			69	45	27	14											
50				71	49	32	20	11									
55					73	53	38	26	17	9							
60						75	56	41	30	21	14	9					
65							78	59	45	34	25	18	13				
70								79	61	48	37	29	22	16	13		
75									80	64	50	40	32	25	20	15	
80										81	66	53	43	35	29	22	16
85											81	68	55	46	37	30	25
90												82	69	58	49	40	32
95	% of Relative Humidity												83	70	58	50	40
100														84	70	61	50
105															85	71	61
110																85	72
115																	86
120																	

Source: C.G. Munger, L.D. Vincent, *Corrosion Prevention by Protective Coatings*, 2nd ed. (Houston, TX, USA: NACE International, 1999), p. 468.

ABSOLUTE ATMOSPHERIC HUMIDITIES AT DIFFERENT TEMPERATURES AND DIFFERENT RELATIVE HUMIDITIES (EXPRESSED AS GRAMS WATER VAPOR/M^3)

	Relative Humidity (%)									
Temperature °C	10	20	30	40	50	60	70	80	90	100
0	0.49	0.98	1.47	1.96	2.45	2.94	3.43	3.92	4.4	4.9
1	0.52	1.04	1.56	2.08	2.60	3.12	3.64	4.16	4.7	5.2
2	0.56	1.12	1.68	2.24	2.80	3.36	2.92	4.48	5.0	5.6
3	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.4	6.0
4	0.64	1.28	1.91	2.56	3.20	3.84	4.48	5.12	5.8	6.4
5	0.68	1.36	2.04	2.72	3.40	4.08	4.76	5.44	6.1	6.8
6	0.73	1.46	2.19	2.92	3.63	4.38	5.11	5.84	6.6	7.3
7	0.77	1.54	2.31	3.08	3.85	4.62	5.39	6.16	6.9	7.7
8	0.83	1.66	2.49	3.32	4.15	4.98	5.81	6.64	7.5	8.3
9	0.88	1.76	2.64	3.52	4.40	5.28	6.16	7.04	7.9	8.8
10	0.94	1.87	2.82	3.76	4.70	5.64	6.58	7.52	8.5	9.4
11	0.99	1.99	2.98	3.98	4.97	5.97	6.96	7.96	8.9	9.9
12	1.06	2.12	3.18	4.24	5.30	6.36	7.42	8.48	9.5	10.6
13	1.13	2.26	3.39	4.52	5.65	6.78	7.91	9.04	10.2	11.3
14	1.20	2.40	3.60	4.80	6.00	7.30	8.40	9.60	10.8	12.0
15	1.28	2.56	3.84	5.12	6.40	7.68	8.96	10.20	11.5	12.8
16	1.35	2.72	4.08	5.44	6.80	8.16	9.52	10.90	12.2	13.6
17	1.45	2.89	4.33	5.78	7.22	8.67	10.10	11.60	13.0	14.5
18	1.54	3.07	4.61	6.14	7.68	9.22	10.80	12.30	13.8	15.4
19	1.63	3.25	4.88	6.51	8.13	9.76	11.40	13.00	14.6	16.3
20	1.72	3.44	5.16	6.88	8.60	10.30	12.00	13.80	15.5	17.2
21	1.82	3.65	5.48	7.30	9.13	11.00	12.80	14.60	16.4	18.2
22	1.93	3.87	5.80	7.44	9.67	11.60	13.50	15.50	17.4	19.3
23	2.05	4.10	6.15	8.20	10.25	12.30	14.30	16.40	18.4	20.5
24	2.17	4.34	6.51	8.68	10.85	13.00	15.20	17.40	19.5	21.7
25	2.29	4.58	6.87	9.16	11.45	13.20	16.00	18.30	20.6	22.9
26	2.42	4.84	7.26	9.68	12.10	14.00	16.90	19.40	21.8	24.2
27	2.56	5.12	7.68	10.25	12.80	15.40	17.90	20.50	23.0	25.6
28	2.71	5.42	8.15	10.85	13.50	16.30	19.00	21.70	24.4	27.5
29	2.86	5.72	8.58	11.44	14.30	17.20	20.00	22.90	25.7	28.6
30	3.02	6.04	9.05	12.10	15.10	18.10	21.10	24.10	27.2	30.2

Source: C.G. Munger, L.D. Vincent, *Corrosion Prevention by Protective Coatings*, 2nd ed. (Houston, TX, USA: NACE International, 1999), p. 36.

VAPOR PRESSURE VS TEMPERATURE FOR VOLATILE COMPOUNDS

Temperature		Propane		Butane		Isobutane		Pentane		Carbon Dioxide		Hydrogen Sulfide		Sulfur Dioxide		Ammonia	
°F	°C	psia	bar	psia	bar	psia	bar	psia	bar	psia	bar	psia	bar	psia	bar	psia	bar
−70	−56.7	7.4	0.51														
−60	−51.1	9.7	0.67													5.5	0.38
−50	−45.6	12.6	0.87													7.7	0.53
−40	−40.0	16.2	1.12											3.1	0.21	10.4	0.72
−30	−34.4	20.3	1.40											4.3	0.30	13.9	0.96
−20	−29.9	25.4	1.75			7.5	0.52			221.	15.24			5.9	0.41	18.3	1.26
−10	−23.3	31.4	2.17			9.3	0.64			262.	18.07			7.9	0.54	23.7	1.63
0	−17.8	38.2	2.63	7.3	0.50	11.6	0.80			309.	21.3			10.4	0.72	30.4	2.10
+10	−12.2	46.0	3.17	9.2	0.63	14.6	1.01			362.	25.0			13.4	0.92	38.5	2.66
20	−6.7	55.5	3.83	11.6	0.80	18.2	1.26			422.	29.1			17.2	1.19	48.2	3.32
30	−1.1	66.3	4.57	14.4	0.99	22.3	1.54			489.	33.7			21.7	1.50	59.7	4.12
40	+4.4	78.0	5.38	17.7	1.22	26.9	1.86			565.	39.0			27.1	1.87	73.3	5.06
50	10.0	91.8	6.33	21.6	1.49	32.5	2.24			650.	44.8	197.	13.6	33.5	2.31	89.2	6.15
60	15.6	107.1	7.39	26.3	1.81	38.7	2.67			744.	51.3	233.	16.0	40.9	2.82	107.6	7.42
70	21.1	124.0	8.55	31.6	2.18	45.8	3.16			849.	58.6	268.	18.5	49.6	3.42	128.8	8.88
80	26.7	142.8	9.85	37.6	2.59	53.9	3.72			964.	66.5	303.	20.9	59.7	4.12	153.0	10.55
90	32.2	164.0	11.31	44.5	3.07	63.3	4.37					349.	24.1	71.2	4.91	180.6	12.46
100	37.8	187.0	12.90	52.2	3.60	73.7	5.08	15.7	1.08			394.	27.2	84.5	5.83	211.9	14.61
110	43.3	213.0	14.19	60.8	4.19	85.1	5.87	19.1	1.32			448.	30.9			247.0	17.03
120	48.9	240.0	16.55	70.8	4.88	98.0	6.76	22.4	1.54			502.	34.6			286.4	19.75
130	54.4			81.4	5.61	112.0	7.72	25.8	1.78			564.	38.9				
140	60.0			92.6	6.39	126.8	8.74	31.5	2.17			630.	43.5				

Source: R.C. Weast, ed., *CRC Handbook*, 55th ed. (Boca Raton, Florida, USA: CRC Press, 1974), p. D-159. Reprinted with permission, copyright CRC Press.

APPROXIMATE pH VALUES AT 25˚C

Solution	Concentration N	g/L	pH	Solution	Concentration N	g/L	pH
Acids				Bases			
Hydrochloric	1	36.5	0.1	Sodium hydroxide	1	40.01	14.0
	0.1	3.65	1.1		0.1	4.00	13.0
	0.01	0.365	2.0		0.01	0.40	12.0
Sulfuric	1	49.0	0.3	Potassium hydroxide	1	56.1	14.0
	0.1	4.9	1.2		0.1	5.61	13.0
	0.01	0.49	2.1		0.01	0.56	12.0
Sulfurous	0.1	4.1	1.5	Sodium carbonate	0.1	5.3	11.6
Ortho-phosphoric	0.1	3.27	1.5	Sodium bicarbonate	0.1	4.2	8.4
Formic	0.1	4.60	2.3	Trisodium phosphate	0.1	5.47	12.0
Acetic	1	60.05	2.4	Ammonia	1	17.03	11.6
	0.1	6.01	2.9		0.1	1.7	11.1
	0.01	0.60	3.4		0.01	0.17	10.6
Carbonic (saturated)			3.8	Calcium carbonate (saturated)			9.4
Hydrogen sulfide	0.1	3.41	4.1	Calcium hydroxide (saturated)			12.4
Hydrocyanic	0.1	2.70	5.1				

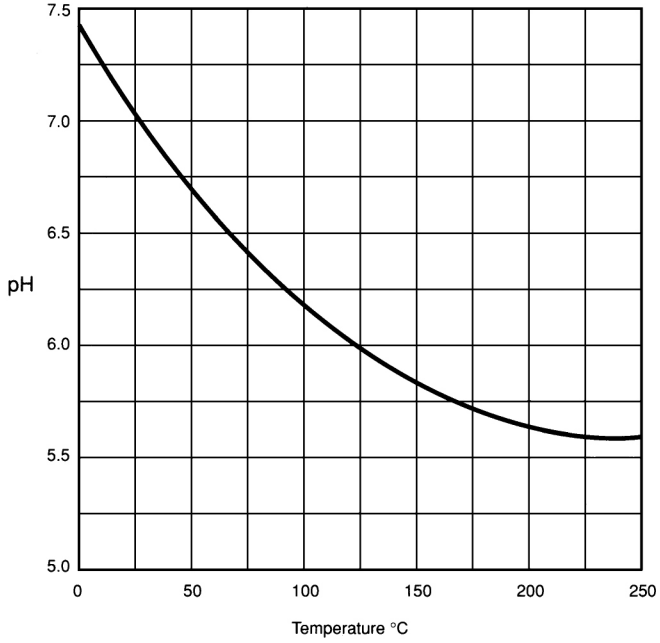
BOILING POINTS VS CONCENTRATION OF COMMON CORROSIVE MEDIA

Concentration, Percent By Weight	Hydrochloric Acid		Sulfuric Acid		Nitric Acid		Phosphoric Acid		Acetic Acid		Formic Acid		Sodium Hydroxide	
	BOILING POINT													
	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
10	219	104	215	102	217	103	212	100	213	101	214	101	218	103
20	230*	110*	219	104	222	106	-		-		215	102	226	108
30	-		226	108	228	109	215	102	-		216	102	241	116
40	-		237	114	234	112	-		-		218	103	262	128
50	-		253	123	242	117	226	108	217	103	-		-	
60	-		284	140	249	121	-		-		222	106	-	
65	-		304	151	251	122	-		-		-		-	
70	-		329	165	250	121	-		-		-		-	
80	-		395	202	-		-		-		-		-	
85	-		437	225	-		316	158	-		222	106	-	
90	-		491	255	-		-		-		-		-	
96	-		554	290	-		-		-		-		-	
98	-		626	330	-		-		-		-		-	
99	-		-		-		-		243	117	-		-	

*Constant Boiling Point Mixture at 20.2 percent concentration.

Source: *Corrosion Resistance of Hastelloy Alloys* (Boston, MA, USA: Cabot Corporation, 1980).

pH VALUES OF PURE WATER AT DIFFERENT TEMPERATURES



SOLUBILITY OF GASES IN WATER

(Partial pressure of the gas = 760 mm Hg)

Temperature		CO_2		H_2S		O_2	
°C	°F	cm^3/L	g/L	cm^3/L	g/L	cm^3/L	g/L
0	32	1713	3.36	4,670	7.09	48.9	0.070
10	50	1194	2.35	3,399	5.16	38.0	0.054
20	68	878	1.72	2,582	3.92	31.0	0.044
30	86	665	1.31	2,037	3.09	26.1	0.037
40	104	530	1.04	1,660	2.52	23.1	0.033
50	122	436	0.86	1,392	2.11	20.9	0.030
60	140	359	0.71	1,190	1.81	19.5	0.028
70	158	-		1,022	1.55	18.3	0.026
80	176	-		917	1.39	17.6	0.025
90	194	-		840	1.28	17.2	0.025
100	212	-		810	1.23	17.0	0.024

SOLUBILITY OF AIR IN WATER AND SOLVENTS

(Air Pressure = 1 Atmosphere)

Temperature			Distilled Water		Sea Water[a]		Ethanol		Iso-Octane	
		Air	O_2		O_2		O_2		O_2	
°C	°F	cm^3/L	cm^3/L	ppm	cm^3/L	ppm	cm^3/L	ppm	cm^3/L	ppm
0	32.0	29.2	10.2	14.6	7.9	11.0	-		-	
1	33.8	28.4	9.9	14.1	-		-		-	
2	35.6	27.7	9.6	13.7	-		-		-	
3	37.4	27.0	9.4	13.4	-		-		-	
4	39.2	26.3	9.1	13.0	-		-		-	
5	41.0	25.7	8.9	12.7	7.0	9.7	-		-	
6	42.8	25.1	8.7	12.4	-		-		-	
7	44.6	24.5	8.5	12.1	-		-		-	
8	46.4	23.9	8.3	11.9	-		-		-	
9	48.2	23.4	8.1	11.6	-		-		-	
10	50.0	22.8	7.9	11.3	6.3	8.7	-		-	
11	51.8	22.3	7.7	11.0	-		-		-	
12	53.6	21.9	7.5	10.7	-		-		-	
13	55.4	21.4	7.4	10.5	-		-		-	
14	57.2	21.0	7.2	10.3	-		-		-	
15	59.0	20.6	7.0	10.1	5.7	7.9	-		-	
16	60.8	20.1	6.9	9.9	-		-		-	
17	62.6	19.8	6.8	9.7	-		-		-	
18	64.4	19.4	6.6	9.5	-		-		-	
19	66.2	19.0	6.5	9.3	-		-		-	
20	68.0	18.7	6.4	9.1	5.2	7.2	44	79	62	126
21	69.8	18.3	6.2	8.9	-		-		-	
22	71.6	18.0	6.1	8.7	-		-		-	
23	73.4	17.7	6.0	8.6	-		-		-	
24	75.2	17.4	5.9	8.4	-		-		-	
25	77.0	17.1	5.8	8.3	4.7	6.6	-		-	
26	78.8	16.8	5.7	8.1	-		-		-	
27	80.6	16.5	5.6	8.0	-		-		-	
28	82.4	16.2	5.5	7.9	-		-		-	
29	84.2	15.9	5.4	7.7	-		-		-	
30	86.0	15.6	5.3	7.6	3.9	5.4	-		-	

(a) Chlorinity = 20.

Solubility of Water in Gasoline

°F	Solubility Gal/1,000 Bbl
40	1.8
50	2.1
60	2.4
70	2.7
80	3.0
90	3.3
100	3.6
110	4.0

Solubility of Water in Specific Hydrocarbons

Hydrocarbon	°C	°F	Solubility mg/100g	Gal/1,000 Bbl
n-Butane	20	68.0	6.5	1.6
Isobutane	19	66.2	6.9	1.7
n-Pentane	15	59.0	6.1	1.6
	24.8	76.6	12.0	3.2
Isopentane	20	68.0	9.4	2.4
n-Hexane	20	68.0	11.1	3.1
Cyclohexane	20	68.0	10.0	3.3
n-Heptane	20	68.0	12.6	3.6
n-Octane	20	68.0	14.2	4.2
Benzene	20	68.0	43.5	16.1
Heptene-1	20.5	68.9	104.7	30.8
Butene-1	20	68.0	39.7	11.1

Source: C.C. Nathan, *Corrosion Inhibitors* (Houston, TX, USA: NACE International, 1981), p. 89.

THERMOCOUPLE DATA

Thermo-Couple	Cu-Const.	Fe-Const.	Ni Cr-Ni	Pt Rh-Pt
+ pole	Copper	Iron	Nickel-Chromium	Platinum-10% Rhodium
− pole	Constantan		Nickel	Platinum

Measuring Temp. °C	Approximate Thermocouple Voltage in mV			
−200	−5.70	−8.15		
−100	−3.40	−4.60		
0	0	0	0	0
100	4.25	5.37	4.04	0.64
200	9.20	10.95	8.14	1.44
300	14.89	16.55	12.24	2.32
400	20.99	22.15	16.38	3.26
500	27.40	27.84	20.64	4.22
600	34.30	33.66	24.94	5.23
700		39.72	29.15	6.27
800		46.23	33.27	7.34
900		53.15	37.32	8.45
1,000			41.32	9.60
1,100			45.22	10.77
1,200			49.02	11.97
1,300				13.17
1,400				14.38
1,500				15.58
1,600				16.76

TEMP. LIMITS

THERMOCOUPLE	Average °C	Intermittent °C
Copper/Constantan	400	600
Iron/Constantan	750	1,000
Nickel-Chromium/Nickel	1,000	1,300
Platinum-Rhodium/Platinum	1,450	1,700