ANALYTICAL LIFE SCIENCE PROCESS

GUIDE

for Infrared Spectroscopy

BRUKER Optics

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IR-Spectroscopy

Chemical Tables

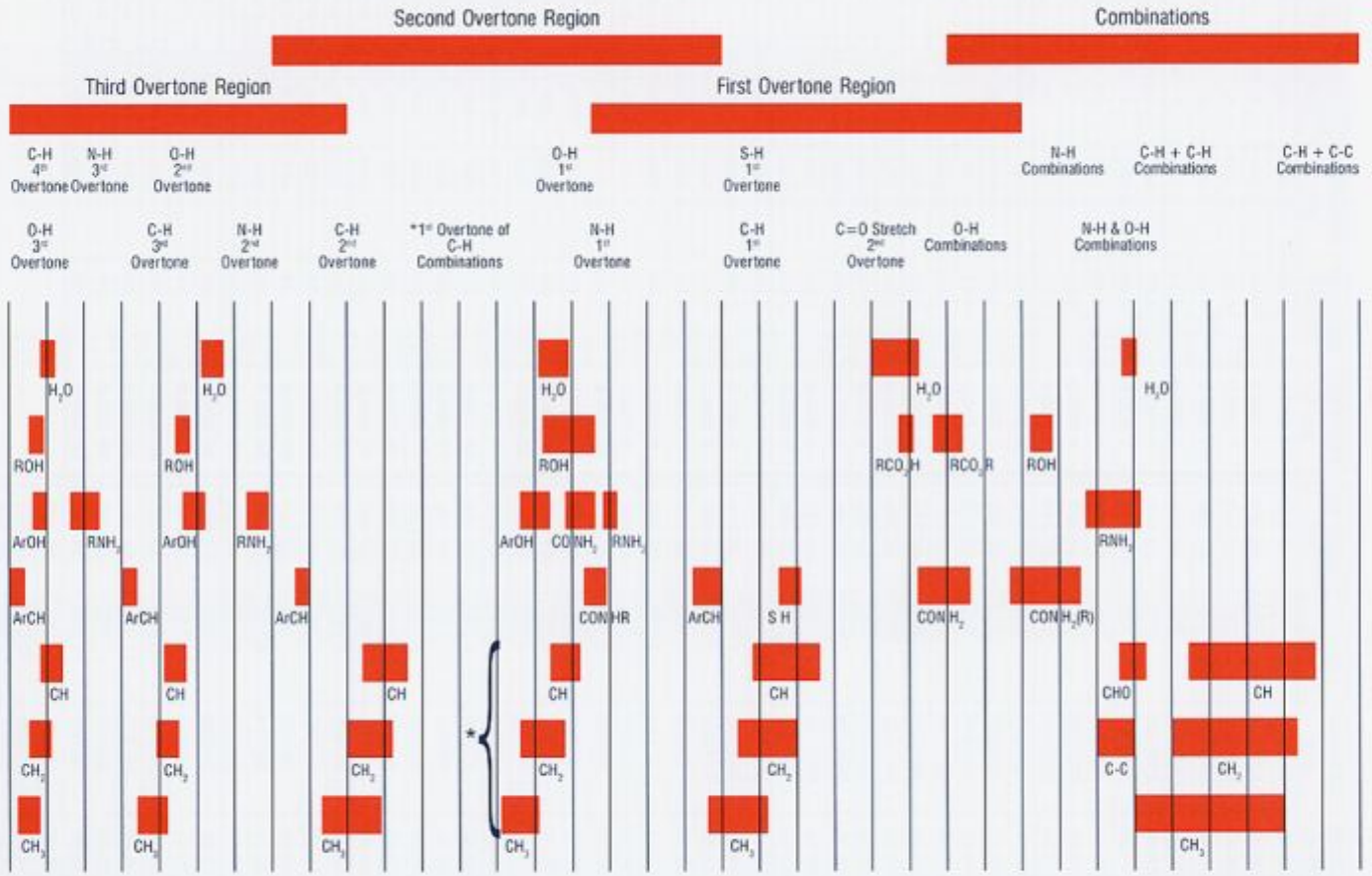
Physical Tables

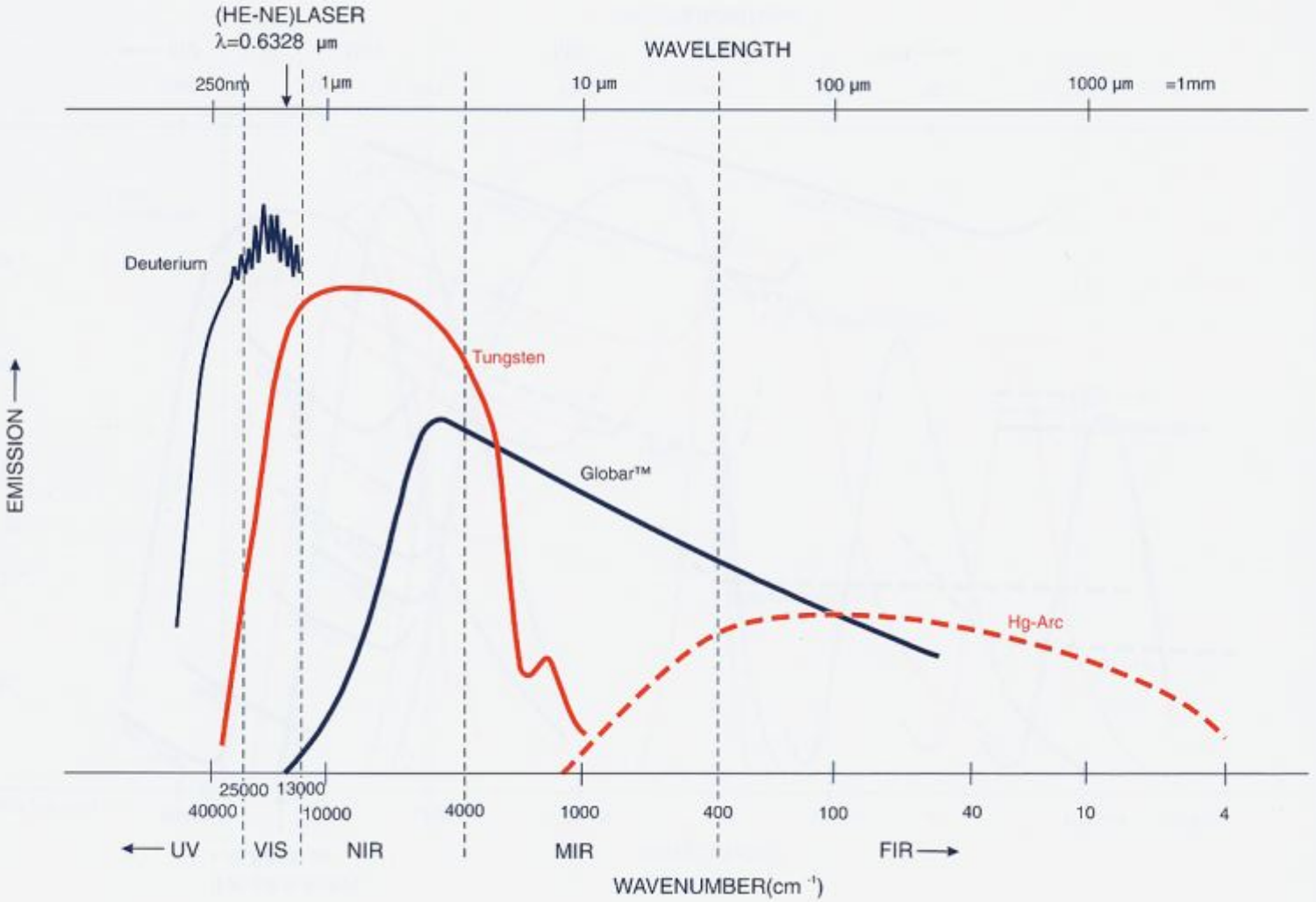
Conversion Table of Energy and Wavelength Units

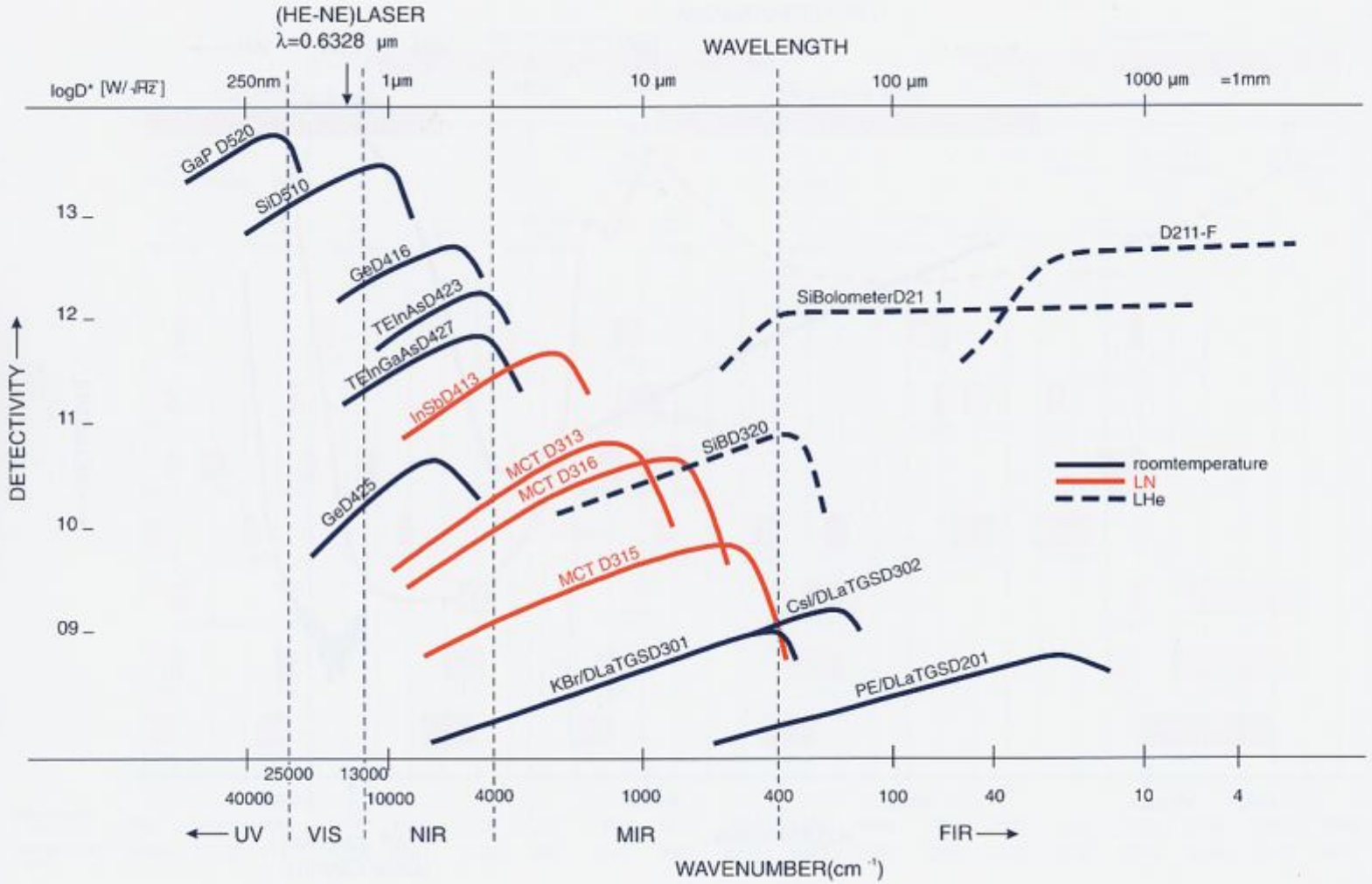
Wavenumber [cm⁻¹]	Wavelength [Micron]	Wavelength [nm]	Frequency [GHz]	Electron Volt [eV]
2.0	5 000.00	5 0000 00	60	.00 025
4.0	2 500.00	2 500 000	120	.00 050
6.0	1 666.67	1 666 667	180	.00 074
8.0	1 250.00	1 250 000	240	.00 099
10.0	1 000.00	1 000 000	300	.00 124
12.0	833.33	833 333	360	.00 149
14.0	714.29	714 286	420	.00 174
16.0	625.00	625 000	480	.00 198
18.0	555.56	555 556	540	.00 223
20.0	500.00	500 000	600	.00 248
22.0	454.55	454 545	660	.00 273
24.0	416.57	416 667	719	.00 298
26.0	384.62	384 615	779	.00 322
28.0	357.14	357 143	839	.00 347
30.0	333.33	333 333	898	.00 372
32.0	312.50	312 500	959	.00 397
34.0	294.12	294 118	1 019	.00 422
36.0	277.78	277 778	1 079	.00 446
38.0	263.16	263 158	1 139	.00 471
40.0	250.00	250 000	1 199	.00 496
50.0	200.00	200 000	1 499	.00 620
60.0	166.67	166 667	1 799	.00 744
70.0	142.86	142 857	2 099	.00 868
80.0	125.00	125 000	2 398	.00 992
90.0	111.11	111 111	2 698	.01 116
100.0	100.00	100 000	2 988	.01 240
110.0	90.91	90 909	3 298	.01 364
120.0	83.33	83 333	3 597	.01 488
130.0	76.92	76 923	3 897	.01 612
140.0	71.43	71 429	4 197	.01 736
150.0	66.67	66 667	4 497	.01 860
160.0	62.50	62 500	4 797	.01 984
170.0	58.82	58 824	5 096	.02 108
180.0	55.56	55 556	5 396	.02 232
190.0	52.63	52 632	5 696	.02 356
200.0	50.00	50 000	5 996	.02 480
220.0	45.45	45 455	6 595	.02 728
240.0	41.67	41 667	7 195	.02 976
260.0	38.46	38 462	7 795	.03 224
280.0	35.71	35 714	8 394	.03 472
300.0	33.33	33 333	8 994	.03 720
320.0	31.25	31 250	9 593	.03 967
340.0	29.41	29 412	10 193	.04 215
360.0	27.78	27 778	10 792	.04 463
380.0	26.32	26 316	11 392	.04 711
400.0	25.00	25 000	11 992	.04 959
500.0	20.00	20 000	14 990	.06 199
600.0	16.67	16 667	17 987	.07 439
700.0	14.29	14 286	20 985	.08 679
800.0	12.50	12 500	23 983	.09 919
900.0	11.11	11 111	26 981	.11 159

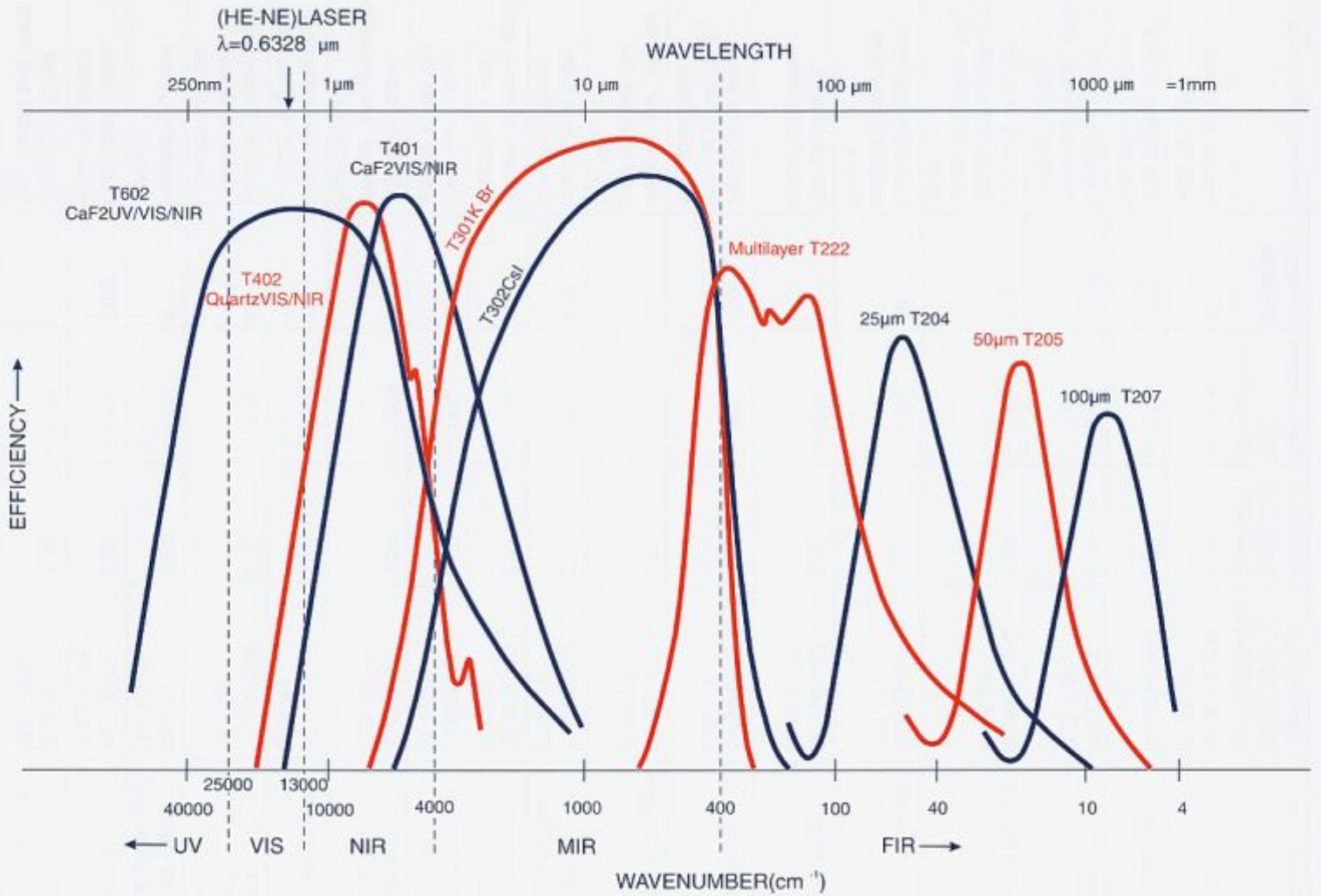
Wavenumber [cm⁻¹]	Wavelength [Micron]	Wavelength [nm]	Frequency [GHz]	Electron Volt [eV]
1 000.0	10.00	10 000	29 979	.12 398
1 100.0	9.09	9 091	32 977	.13 638
1 200.0	8.33	8 333	35 975	.14 878
1 300.0	7.69	7 692	38 973	.16 118
1 400.0	7.14	7 143	41 971	.17 358
1 500.0	6.67	6 667	44 968	.18 598
1 600.0	6.25	6 250	47 966	.19 837
1 700.0	5.88	5 882	50 964	.21 077
1 800.0	5.56	5 556	53 962	.22 317
1 900.0	5.26	5 263	56 960	.23 557
2 000.0	5.00	5 000	59 958	.24 797
2 200.0	4.55	4 545	65 954	.27 276
2 400.0	4.17	4 167	71 950	.29 756
2 600.0	3.85	3 846	77 945	.32 236
2 800.0	3.57	3 571	83 941	.34 716
3 000.0	3.33	3 333	89 937	.37 195
3 200.0	3.13	3 125	95 933	.39 675
3 400.0	2.94	2 941	101 929	.42 155
3 600.0	2.78	2 778	107 924	.44 634
3 800.0	2.63	2 632	113 920	.47 114
4 000.0	2.50	2 500	119 916	.49 594
5 000.0	2.00	2 000	149 895	.61 992
6 000.0	1.67	1 667	179 874	.74 390
7 000.0	1.43	1 429	209 853	.86 789
8 000.0	1.25	1 250	239 832	.99 187
9 000.0	1.11	1 111	269 811	1.11 586
10 000.0	1.00	1 000	299 790	1.23 984
11 000.0	.91	909	329 769	1.36 382
12 000.0	.83	833	359 748	1.48 781
13 000.0	.77	769	389 727	1.61 179
14 000.0	.71	714	419 706	1.73 578
15 000.0	.67	667	449 685	1.85 976
16 000.0	.62	625	479 664	1.98 374
17 000.0	.59	588	509 643	2.10 773
18 000.0	.56	556	539 622	2.23 171
19 000.0	.53	526	569 601	2.35 570
20 000.0	.50	500	599 580	2.47 968
22 000.0	.45	455	659 538	2.72 765
24 000.0	.42	417	719 496	2.97 562
26 000.0	.38	385	779 454	3.22 358
28 000.0	.36	357	839 412	3.47 155
30 000.0	.33	333	899 370	3.71 952
32 000.0	.31	312	959 328	3.96 749
34 000.0	.29	294	1 019 286	4.21 546
36 000.0	.28	278	1 079 244	4.46 342
38 000.0	.26	263	1 139 202	4.71 139
40 000.0	.25	250	1 199 160	4.95 936

Near Infrared Table




(HE-NE)LASER
λ=0.6328 µm
WAVELENGTH
250nm
1µm
10 µm
100 µm
1000 µm
=1mm
Deuterium
Tungsten
Globar™
Hg-Arc
EMISSION
25000
13000
40000
10000
4000
1000
400
100
40
10
4
UV
VIS
NIR
MIR
FIR
WAVENUMBER(cm -1)

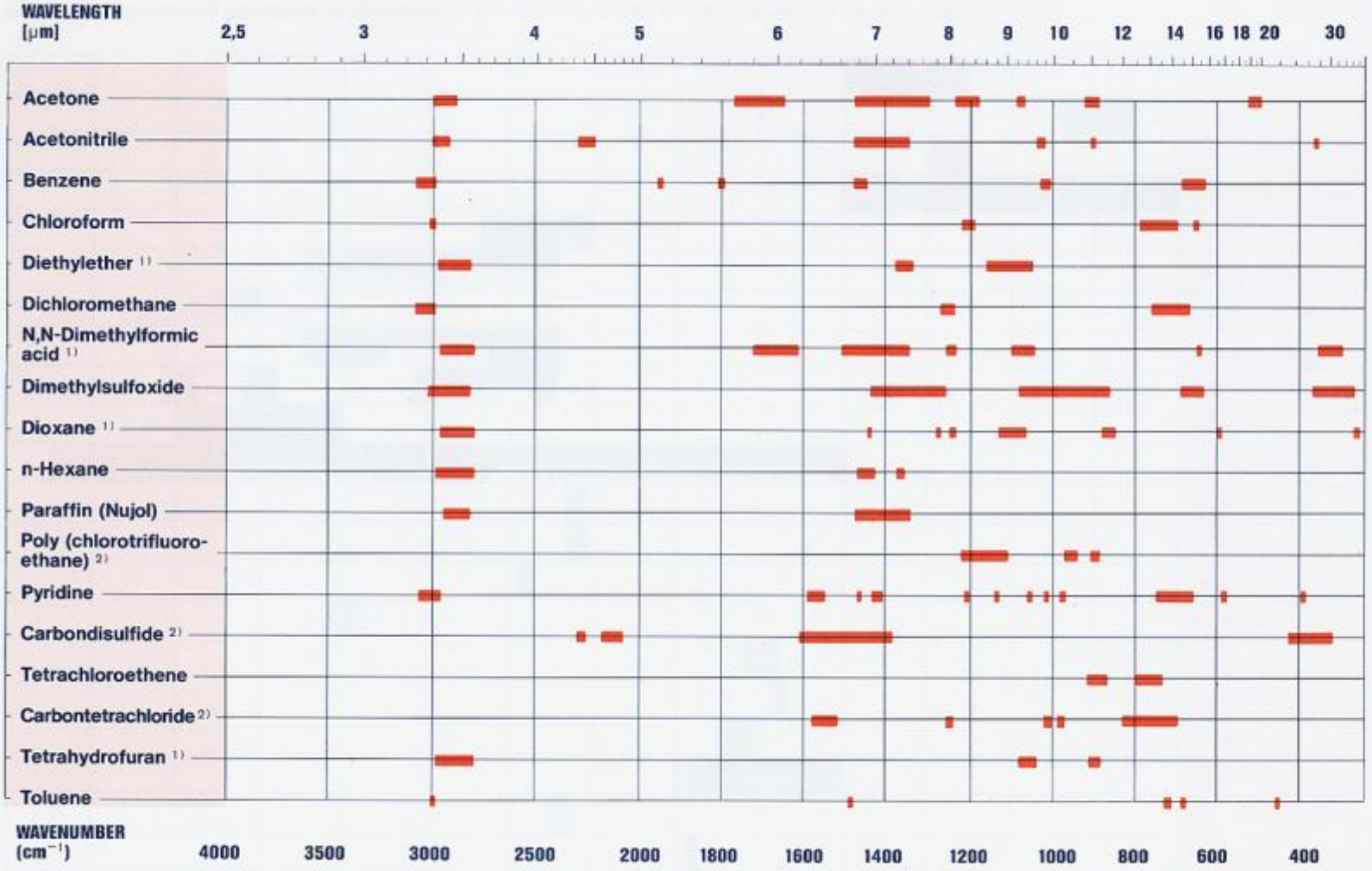

(HE-NE)LASER
λ=0.6328 µm
WAVELENGTH
logD* [W/√Hz]
250nm
1µm
10 µm
100 µm
1000 µm
=1mm
GaP D520
SiD510
GeD416
TEInAsD423
TEInGaAsD427
InSbD413
MCT D313
MCT D316
MCT D315
GeD425
SiBD320
SiBolometerD21 1
D211-F
roomtemperature
LN
LHe
CsI/DLaTGSD302
KBr/DLaTGSD301
PE/DLaTGSD201
DETECTIVITY
13
12
11
10
09
25000
13000
40000
10000
4000
1000
400
100
40
10
4
UV
VIS
NIR
MIR
FIR
WAVENUMBER(cm -1)


(HE-NE)LASER
λ=0.6328 µm
WAVELENGTH
250nm
1µm
10 µm
100 µm
1000 µm =1mm
T602
CaF2UV/VIS/NIR
T401
CaF2VIS/NIR
T301K Br
T302CsI
T402
QuartzVIS/NIR
Multilayer T222
25µm T204
50µm T205
100µm T207
EFFICIENCY
25000
13000
40000
10000
4000
1000
400
100
40
10
4
UV
VIS
NIR
MIR
FIR
WAVENUMBER(cm⁻¹)

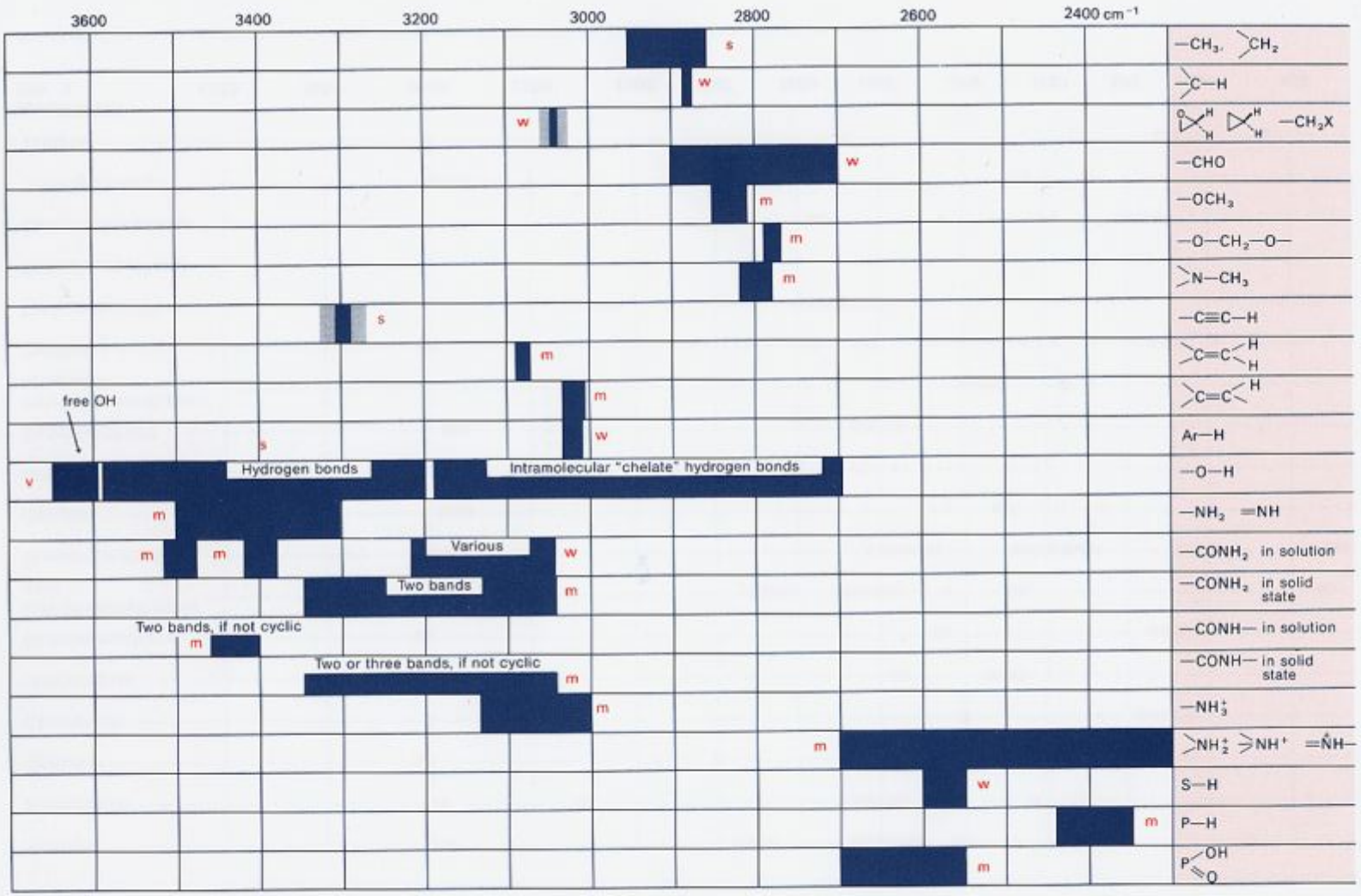
IR-Window Material

Material	Transmission Range [cm^{-1}] ([micrometers])	Refractive Index n at 2000 cm^{-1}	Reflectance loss per surface	Hardness (Knoop)	Chemical Properties
Infrasil SiO_2	57,000-2,800 (0.175-3.6)	1.46	~ 3.3 %	461	Insoluble in water; soluble in HF.
UV Sapphire AL_2O_3	66,000-2,000 (0.15-5.0)	1.75	~ 7.3 %	1370	Very slightly soluble in acids and bases.
Silicon Si	10,000-100 (1.0-100)	3.42	~ 30 %	1150	Insoluble in most acids and bases; soluble in HF and HNO_3.
Calcium Fluoride CaF_2	66,000-1,200 (0.15-8.0)	1.40	~ 2.8%	158	Insoluble in water; resists most acids and bases; soluble in NH_4 salts.
Barium Fluoride BaF_2	50,000-900 (0.2-11)	1.45	~ 3.3%	82	Low water solubility; soluble in acid and NH_4Cl.
Zinc Sulfide, Cleartran ZnS	22,000-750 (0.45-13.0)	2.25	~ 15%	355	Soluble in acid; insoluble in water.
Germanium Ge	5,000-600 (2.0-17)	4.01	~ 36%	550	Insoluble in water; soluble in hot H_2SO_4 and aqua regia.
Sodium Chloride NaCl	28,000-700 (0.35-15)	1.52	~ 4.5%	15	Hygroscopic; slightly soluble in alcohol and NH_3.
AMTIR GeAsSe Glass	11,000-900 (0.9-11)	2.50	~ 18%	170	Insoluble in water. Soluble in bases.
Zinc Selenide ZnSe	20,000-500 (0.5-20)	2.43	~ 17%	150	Soluble in strong acids; dissolves in HNO_3.
Silver Chloride AgCl	23,000-400 (0.42-25)	2.00	~ 11%	10	Insoluble in water; soluble in NH_4OH.
Potassium Bromide KBr	33,000-400 (0.3-25)	1.54	~ 4.5 %	7	Soluble in water, alcohol, and glycerine; hygroscopic.
Cesium Iodide CsI	33,000-150 (0.3-70)	1.74	~ 7.3%	20	Soluble in water and alcohol; hygroscopic.
KRS-5 TlBr/I	16,000-200 (0.6-60)	2.38	~ 17%	40	Soluble in warm water; soluble in bases; insoluble in acids.
Polyethylene PE (high density)	600-10 (16-1,000)	1.52	~ 4.5%	5	Resistant to most solvents.
Diamond C	45,000-10 (0.22-1,000)	2.40	~ 17%	7000	Insoluble in water, acids, and bases.
TPX(TM) Methylpentene Resin	350-10 (28-1,000)	1,43	~ 3.3%		Similar to PE but transparent and more rigid

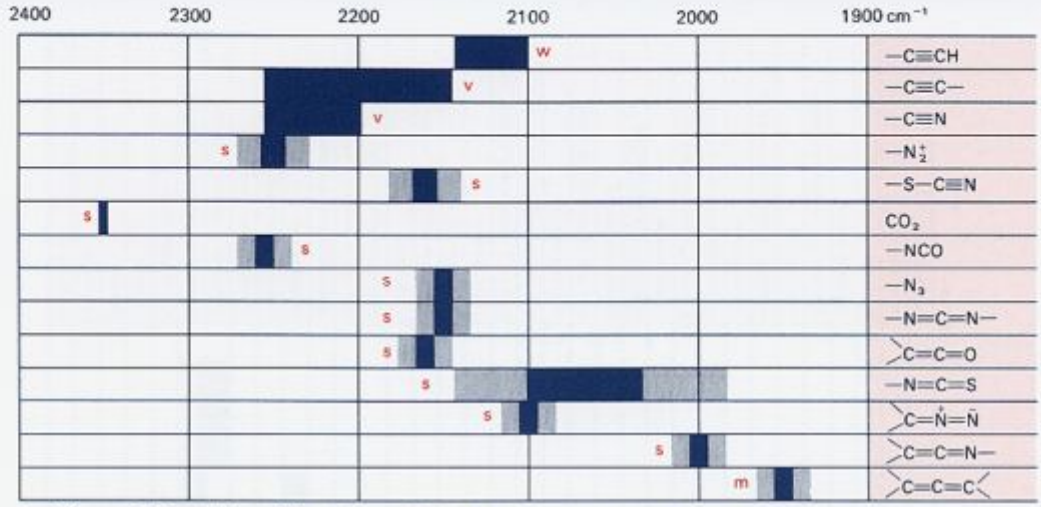
Absorption of Commonly Used IR Solvents*



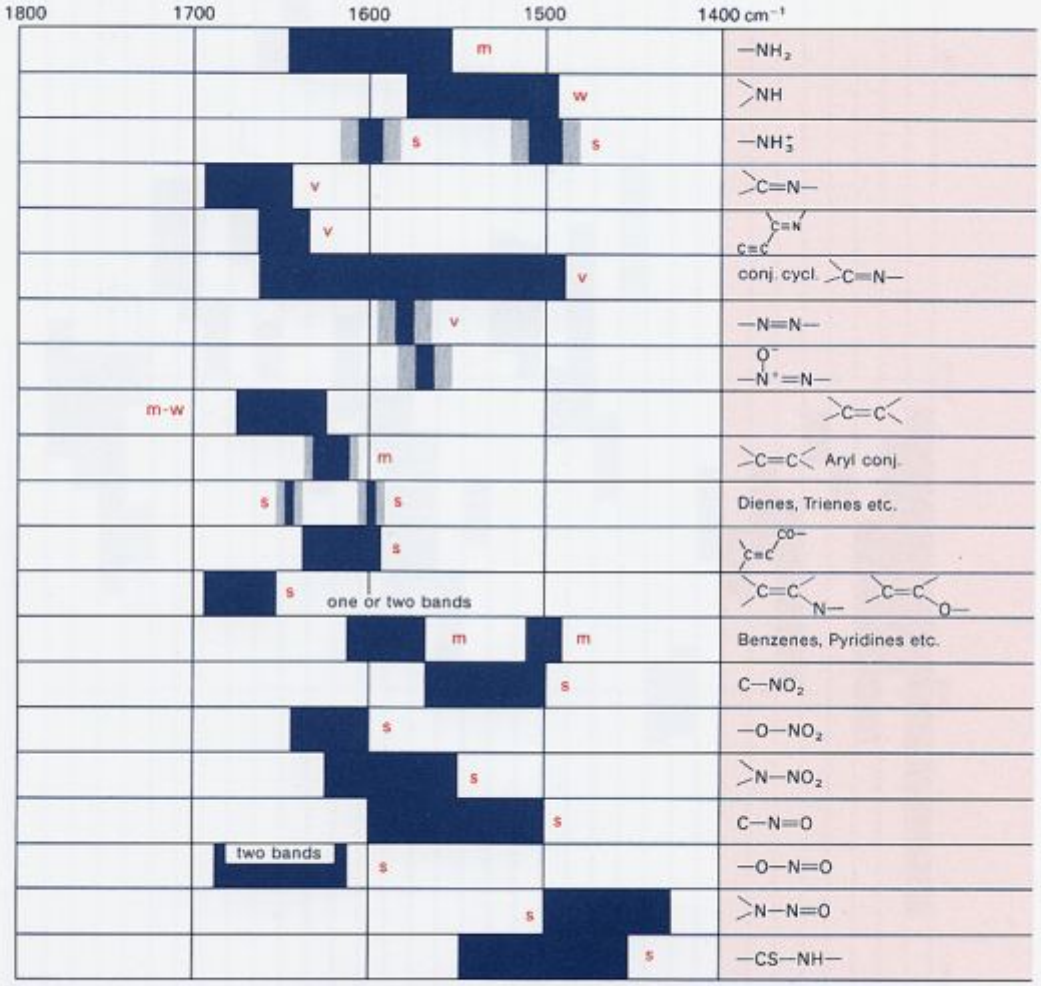
* This chart shows ranges with transmission less than 20%; standard thickness: 100 µm; except for: (1) 20 µm; (2) 200 µm.



Positions of Stretching Vibrations of Hydrogen (in the hatched ranges the boundaries are not well defined);
Band intensity: s = strong, m = medium, w = weak, v = varying.

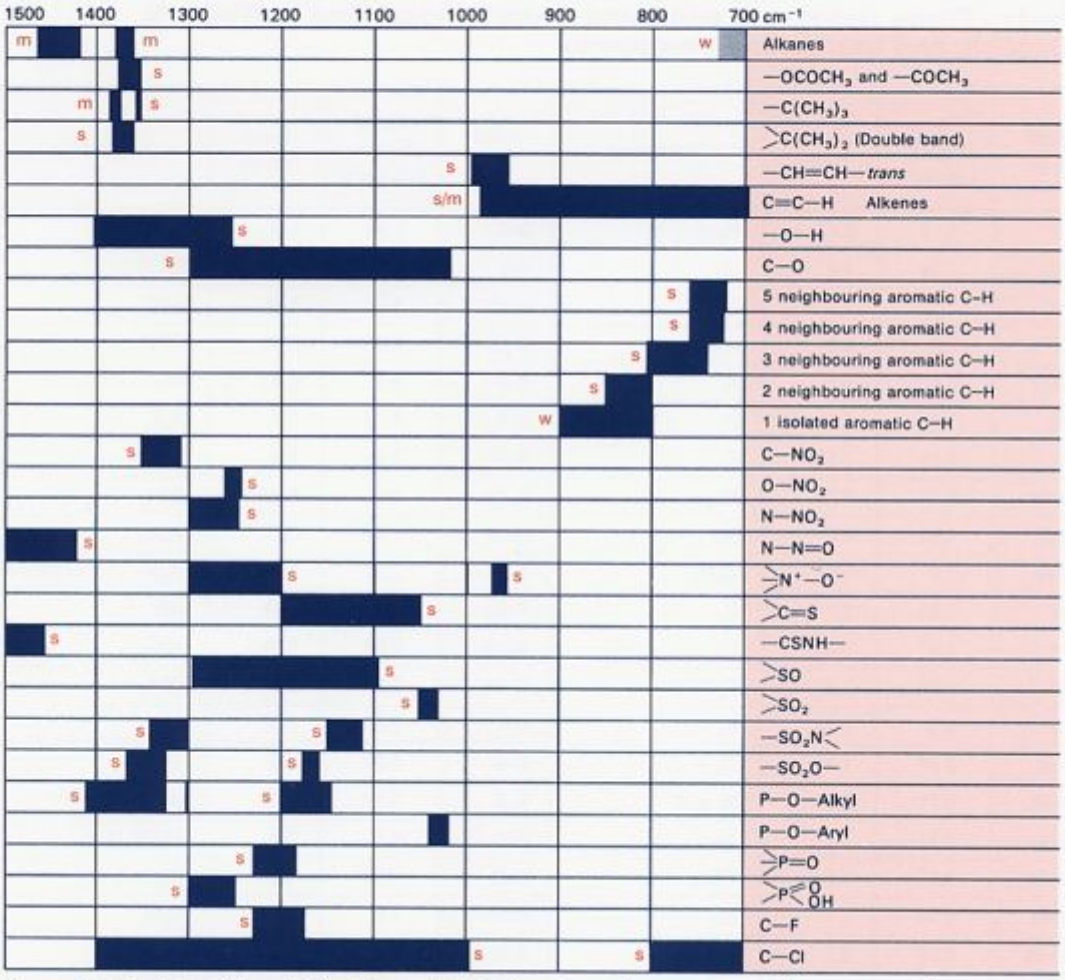


Positions of Stretching Vibrations of Triple Bonds and Cumulated Double Bonds
(s = strong, m = medium, w = weak, v = varying)



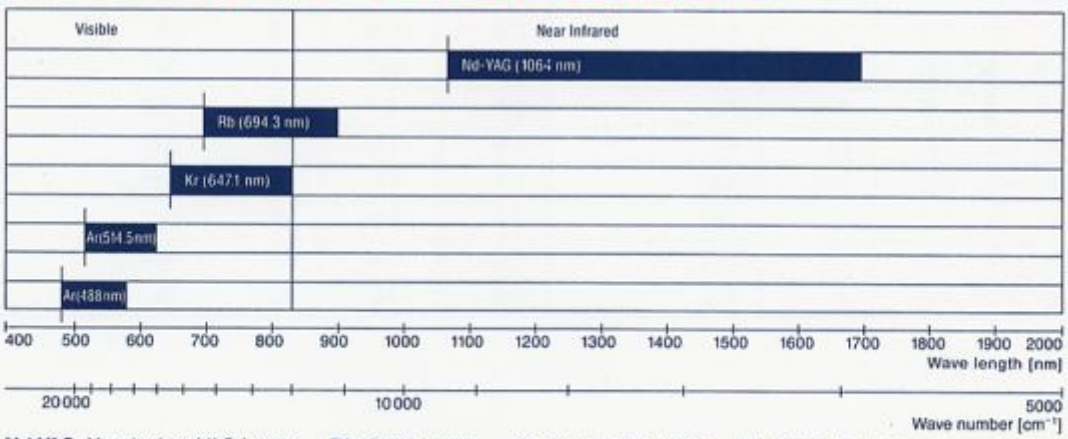
Positions of the Double Bond Stretching Vibrations and N-H Bending Vibrations
(s = strong, m = medium, w = weak, v = varying)

Positions of Carbonyl Stretching Vibrations (all bands are strong)



Characteristic Absorptions in the Fingerprint Region (s = strong, m = medium, w = weak)

Stokes Shifts (0-3500 cm^{-1}) of Various Laser Sources



Nd-YAG: Neodynium YAG Laser **Rb:** Ruby Laser **Kr:** Krypton Ion Laser **Ar:** Argon Ion Laser

Selected Force Constants and Bond Orders (according to Siebert) of Organic and Inorganic Compounds

Bond A–B	Force Const. f (N cm^{-1})	Bond Order	Compound	Bond A–B	Force Const. f (N cm^{-1})	Bond Order	Compound
H-H	5.14	0.77	H_2	H-O	7.40	1.0	HO^-
Li-Li	1.24	1.2	Li_2	H-F	8.85	1.1	HF
B-B	3.58	1.2	B_2	H-Al	1.76	0.60	AlH_4^-
C-C	16.5	3.2	HCCH	H-Si	2.98	0.84	SiH_4
N-N	22.42	3.2	N_2	H-P	3.11	0.82	PH_3
O-O	11.41	1.4	O_2	H-S	4.29	1.0	H_2S
F-F	4.45	0.58	F_2	H-Cl	4.81	1.0	HCl
Na-Na	0.17	0.24	Na_2	H-Ge	2.81	0.82	GeH_4
Si-Si	4.65	2.0	Si_2	H-As	2.85	0.81	AsH_3
Si-Si	~1.7	~0.9	Si_2H_6	H-Se	3.51	0.93	H_2Se
P-P	5.56	2.1	P_2	H-Br	3.84	0.98	HBr
P-P	2.07	0.95	P_4	H-Sn	2.03	0.76	SnH_4
S-S	4.96	1.7	S_2	H-Sb	2.09	0.77	SbH_3
S-S	2.5	0.99	S_8	H-I	2.92	0.97	HI
Cl-Cl	3.24	1.1	Cl_2	C-H	5.50	1.0	CH_4
Ni-Ni	0.11	0.2	Ni solid	C-B	3.82	1.1	$B(CH_3)_3$
As-As	3.91	1.8	As_2	C-C	16.5	3.2	HCCH
Se-Se	3.61	1.6	$^{80}Se_2$	C-C	9.15	1.9	H_2CCH_2
Br-Br	2.36	1.1	Br_2	C-C	7.6	1.7	C_6H_6
Rb-Rb	0.08	0.2	Rb_2	C-C	4.4	1.1	H_3CCH_3
Cd-Cd	1.11	1.0	Cd_2^{2+}	C-N	18.07	3.0	HCN
Sb-Sb	2.61	1.9	Sb_2	C-N	11.84	2.1	CN_2^{2-}
Te-Te	2.37	1.7	Te_2	C-N	6.54	1.3	$NNCH_2$
I-I	1.70	1.2	I_2	C-O	18.56	2.8	CO
Hg-Hg	1.69	1.5	Hg_2^{2+}	C-O	15.61	2.4	CO_2
Pb-Pb	4.02	3	Pb_2	C-O	12.76	2.0	OCH_2
Bi-Bi	1.84	1.6	Bi_2	C-O	7.86	1.3	CO_3^{2-}
H-B	2.75	0.68	BH_3	C-O	5.1	0.96	$O(CH_3)_2$
H-C	5.50	1.0	CH_4	C-F	6.98	1.1	CF_4
H-N	7.05	1.1	NH_3	C-P	8.95	2.4	HCP
H-O	8.45	1.1	H_2O	C-S	7.67	2.0	CS_2

Selected Force Constants and Bond Orders (according to Siebert) of Organic and Inorganic Compounds

Bond A–B	Force Const. f (N cm^{-1})	Bond Order	Compound	Bond A–B	Force Const. f (N cm^{-1})	Bond Order	Compound
C-S	3.3	1.0	$S(CH_3)_2$	O-O	6.18	0.89	O_2^-
C-Cl	3.12	0.93	CCl_4	O-O	5.70	0.83	O_3
C-Ni	2.91	1.2	Ni_4CO	O-Na	~3.2	~1.1	Na-OH
C-Ni	1.43	0.68	NiCO	O-Mg	3.5	1.1	MgO
C-Se	5.94	1.8	CSe_2	O-Al	5.66	1.5	AlO
C-Br	2.42	0.86	CBr_4	O-Al	3.8	1.1	$Al(OH)_4^-$
C-Rh	2.4	1.2	$(Rh(CN)_6)^{3-}$	O-Si	9.25	2.1	SiO
C-Ag	2.0	0.99	$(Ag(CN)_2)^-$	O-Si	4.75	1.2	SiO_4^{-4}
C-I	1.69	0.79	CI_4	O-P	9.41	2.0	PO
N-H	7.05	1.1	NH_3	O-P	6.16	1.4	PO_4^{3-}
N-B	7.2	1.6	BN_2^{3-}	O-S	10.01	2.0	SO_2
N-C	18.07	3.0	HCN	O-Cl	4.26	1.0	ClO_2^-
N-N	22.42	3.2	N_2	O-Cl	3.30	0.82	ClO^-
N-N	16.01	2.4	N-NNH	O-Ca	2.85	1.2	CaO
N-N	13.15	2.0	$N\text{-}N\text{-}N^-$	O-Ti	7.19	2.4	TiO
N-O	25.07	3.1	$N\text{-}O^+$	O-V	7.36	2.3	VO
N-O	17.17	2.3	NO_2^+	O-Cr	5.82	1.9	CrO
N-O	15.49	2.1	NO	O-Mn	5.16	1.6	MnO
N-O	15.18	2.0	ONCl	O-Fe	5.67	1.7	FeO
N-O	11.78	1.7	NNO	O-Cu	2.97	0.93	CuO
N-F	4.16	0.66	NF_3	O-Ge	7.53	1.8	^{74}GeO
N-Si	3.8	1.1	$((CH_3)_3Si)_2NH$	O-Se	6.45	1.5	SeO
N-S	12.54	2.5	NSF_3	O-Mo	3.05	1.2	Ba_2CaMoO_6 (solid)
N-S	8.3	1.9	HNSO	O-Ru	6.70	2.2	RuO_4
N-S	3.1	0.87	$H_3N\text{-}SO_3$	O-Ag	2.00	0.79	AgO
O-Li	1.58	0.66	LiO	O-Sn	5.53	1.7	SnO
O-Be	7.51	1.8	BeO	O-Te	5.31	1.6	TeO
O-B	13.66	2.5	BO	O-Ba	3.79	1.8	BaO
O-B	6.35	1.3	BO_3^{3-}	O-Ce	6.33	2.6	CeO
O-O	16.59	2.0	O_2^+	O-Pr	5.68	2.4	PrO
O-O	11.41	1.4	O_2	O-Nd	3.5	1.6	$NdAc_3 \cdot H_2O$ (polymer)

Properties of Some Important Solvents

Solvent	Abbreviation	Formula	Molecular weight	F. p. (°C)	B. p. (°C)	Density	Dipole Mom.**	Susceptib. $-\chi \cdot 10^6$	Dielectr. Const.	Refract. Index	Chemical Shift δ ^{1}H (ppm)	Chemical Shift δ ^{13}C (ppm)
Acetic acid		$C_2H_4O_2$	60·0$_5$	16·7	117·9	1·049	1·2	0·551(32°)	6·1	1·3719	2·1	21·1 177·3
Acetone	AC	C_3H_6O	58·1	-94·7	56·3	0·790	2·88	0·460	20·7	1·3587	2·05	30·50 205·1
Acetonitryle	AN	C_2H_3N	41·0$_5$	-44	81·6	0·777	3·92	0·534	37·5	1·3416	1·93	1·28 118·10
Benzene*		C_6H_6	78·1	5·5	80·1	0·879	0	0·699 (22°)	2·3	1·5011	7·16	128·70
t-Butyl alcohol	t-BuOH	$C_4H_{10}O$	74·1	25·5	82·2	0·789	1·66	0.534	1·8	1·3878	1·3	31·6 68.7
Carbon disulfide		CS_2	76·1	-111·6	46·2	1·270	0	0·532	2·6	1·6319		192·8
Carbon tetrachloride*		CCl_4	153·8	-23	76·7	1·584	0	0· 691	2·2	1· 4574		96·7
Chloroform*		$CHCl_3$	119.4	-63·5	61·1	1·480	1·01	0·740	4·8	1·4429	7·26	77·36
Cyclohexane		C_6H_{12}	84·2	6·6	80·7	0·774	0	0·627	2·0	1·4235	1·4	27·8
Cyclopentane		C_5H_{10}	70·1	-93·8	49·3	0.745		0·629	2·0	1·4065	1·5	26·5
Decaline		$C_{10}H_{18}$	138·2	-43	191·7	0·879		0·681		1·4758	0·9 to 1·8	24 to 44
Dibromomethane		CH_2Br_2	173·8	-52·6	97·0	1·5420	1·43	0·935	7·5	2·497	5·0	21·6
o-Dichlorobenzene*	ODCB	$C_6H_4Cl_2$	147·0	-17	180·5	1·306	2·50	0·748	9·9	1·5515	7·0 to 7·4	128 to 133
Diethylether		$C_4H_{10}O$	74·1	-116·2	34·5	0·7138	1·15		4·3	1·3526	1·2 3·5	17·1 67·4
1,2-Dichloroethane		$C_2H_4Cl_2$	99·0	-35·7	83·5	1·246	1·75		10·4	1·4421	3·7	51·7
1,2-Dichloroethylene Z		$C_2H_2Cl_2$	96·9	-80·0	60·6	1·284	1·90	0·679 (15°)	9·2	1·4490	6·4	119·3
1,2-Dichloroethylene E		$C_2H_2Cl_2$	96·9	-49·8	47·7	1·255	0	0·638 (15°)	2·1	1·4462	6·3	121·1
1,1-Dichloroethylene		$C_2H_2Cl_2$	96·9	-122·6	31·6	1·213	1·34	0·635 (15°)	4·6	1·4247	5·5	115·5 128·9
Dichloromethane		CH_2Cl_2	84·9	-95·1	39·8	1·315	1·60	0·733	8·9	1·4211	5·31	53·73
Dimethoxymethane		$C_3H_8O_2$	76·1	-105·2	42·3	0·866		0·611	2·6	1·3563	3·3 4·4	54·8 97·9
Dimethylacetamide	DMA	C_4H_9NO	87·1	-20·0	166·1	0·937	3·8		37·8	1·4356	2·1 3	34/38 169·6
Dimethylcarbonate*		$C_3H_6O_3$	90·1	3	90·5	1·069				1·3687	3·65	54·8 156.9
Dimethylether		C_2H_6O	46·1	-139	-24							59·4
N,N-Dimethylformamide	DMF	C_3H_7NO	73·1	-60·4	153·0	0·944	3·86		36·7	1·4282	2·9 8·0	30·10 35·2 162·5
Dimethylsulfoxide	DMSO	C_2H_6SO	78·1	18·5	189·0	1·096	3·96		46·7	1·4773	2·49	39·50
Dioxane*	D	$C_4H_8O_2$	88·1	11·8	101·3	1·028	0·45	0·606 (32°)	2·2	1·4203	3·53	66·30

Properties of Some Important Solvents

Solvent	Abbreviation	Formula	Molecular weight	F. p. (°C)	B. p. (°C)	Density	Dipole Mom.**	Susceptib. $-\chi \cdot 10^6$	Dielectr. Const.	Refract. Index	Chemical Shift δ ^{1}H (ppm)	Chemical Shift δ ^{13}C (ppm)
Ethanol	EtOH	C_2H_6O	46·1	-114·1	78·3	0·785	1·69	0·575	24·5	1·3594	1·10	17·20 56·70
Ethyl acetate		$C_4H_8O_2$	88·1	-83·9	77·1	0·895	1·8	0·554	6·0	1·3698	1·2/2·0 4·1	14·3 60·1 170·4
Ethylene carbonate	EC	$C_3H_4O_3$	88·1	36·4	238	1·321	4·91		89·6	1·4250	4·4	65·0 155·8
Freon 12		CF_2CL_2	120·9	-158	-29·8	1·18	0·5	0·642 (30°)				
Freon 22		$CHClF_2$	86·5	-146	-40·8	1·491	1·4					
Formamide	F	CH_3ON	45·0	2·6	210·5	1·133	3·73	0·551	109	1·4475	7·2 8·1	165·1
Hexachloroacetone		C_3Cl_6O	264·8	-30	203	1·744				1·5112		123·7 126·4
Hexafluorodichloro-propane		$C_3F_6Cl_2$	220·9	-136	35	1·589						
Hexamethyl-phosphoramide*	HMPT	$C_6H_{18}N_3PO$	179·2	7·2	233	1·027	5·39		30·0	1·4588	2·4 2·6	36·6
Methanol	MeOH	CH_4O	32·0	-97·7	64·7	0·787	1·70	0·530	32·7	1·3265	3·31	49·0
Methyl chloride		CH_3Cl	50·5	-97·7	-24·1	0·916	1·87		12·6	1·3389		25·1
Morpholine		C_4H_9NO	87·1	-3·1	128·9	1·005		0·631	7·4	1·4573	2·6 3·9	46·8 68·9
Nitromethane		CH_3NO_2	61·0	-28·5	101·2	1·131	3·46	0·391 (25°)	35·9	1·3796	4·33	62·80
Pyridine		C_5H_5N	79·1	-41·6	115·3	0·978	2·2	0·611	12·4	1·5075	7·21 7·57 8·72	123·50 135·50 149·50
Quinoline		C_9H_7N	129·2	-14·9	237·1	1·098	2·2	0·729	9·0	1·6293	7 to 8·8	121 to 151
Sulfur dioxide		SO_2	64·1	-72·7	-10·0	1·434	1·6		17·6			
2,2-Tetrachloroethane		$C_2H_2Cl_4$	167·8	-43·8	146·2	1·578	1·3	0·856	8.2	1·4868	6·0	74·0
Tetrachloroethane		C_2Cl_4	165·8	-22·3	121·2	1·631		0·802 (15°)	2·3	1 ·5076		120·4
Tetrahydrofuran	THF	C_4H_8O	72·1	-66	66·0	0·889	1·75		7·6	1·4050	1·72 3·57	25·26 67·2
Tetramethylurea	TMU	$C_5H_{12}N_2O$	116·2	-1·2	176·5	0·969	3·47	0·634 (15°)	23·1	1·4459	2·8	38·5 165·6
Toluene		C_7H_8	92·1	-94·9	110·6	0·867	0·36	0·618	2·4	1·4969	2·09 7·01 7·09	21·3 138·5
Trichloroethylene*		C_2CHl_3	131·4	-73	87·2	1·476		0·734	3·4	1·4800	6·4	116·7 124·0
Water		H_2O	18·02	0	100	0·997	1·85	0·719	78·5	1·3329	4·72	

B.p: boiling point F.p: freezing point Reference of the shifts: ^{1}H and ^{13}C (TMS) * Carcinogens or cancer suspect angents

** Dipole moment in Duebye units: (1D = 10^{-18} e.s.u. cm ≙ 3.3356 x 10^{-30} C m)

SI Unit System (Système International)

Fundamental SI Quantities	Name	Symbol	
Length	Meter	m	
Mass	Kilogram	kg	
Time	Second	s	
Electric Current	Ampere	A	
Thermodynamic Temperature	Kelvin	K	
Amount of Substance	Mole	mol	
Light Intensity, Luminosity	Candela	cd	
Special SI-derived Quantities	**Name**	**Symbol**	**Units**
Frequency	Hertz	Hz	s^{-1}
Plane Angle Angular Frequency	Radian	rad	2π rad = 360°, 1 rad = 57.2957795° rad s^{-1} [1 Hz = 2π rad s^{-1}]
Solid Angle	Steradian	sr	4π sr = sphere
Force	Newton	N	m kg s^{-2}
Pressure, Stress	Pascal	Pa	N m^{-2} = m^{-1} kg s^{-2} [1 bar = 10^5 Pa]
Energy, Work, Heat	Joule	J	N m = m^2 kg s^{-2}
Power, radiant flux	Watt	W	J s^{-1} = m^2 kg s^{-3}
Electric Charge	Coulomb	C	A s
Electric potential, emf	Volt	V	J C^{-1} = m^2 kg s^{-3} A^{-1}
Electrical Resistance	Ohm	Ω	V A^{-1} = m^2 kg s^{-3} A^{-2}
Electrical Conductance	Siemens	S	Ω^{-1} = m^{-2} kg^{-1} s^3 A^2
Electrical Capacitance	Farad	F	C V^{-1} = m^{-2} kg^{-1} s^4 A^2
Magnetic Flux	Weber	Wb	V s = m^2 kg s^{-2} A^{-1}
Magnetic Flux Density	Tesla	T	Wb m^{-2} = V s m^{-2} = kg s^{-2} A^{-1}
Inductance	Henry	H	V A^{-1} s = m^2 kg s^{-2} A^{-2}
Celsius Temperature	°C	K	°C = Temp.(K) – 273.15
Light Flux	Lumen	lm	cd sr
Illuminance	Lux	lx	cd sr m^{-2}
Activity (radioactive decay)	Becquerel	Bq	s^{-1} [1 Curie (Ci) = 37 GBq]
Absorbed Dose	Gray	Gy	J kg^{-1} = m^2 s^{-2} [1 rad = 0.01 Gy]
Equivalent Dose, Energy Dose	Sievert	Sv	J kg^{-1} = m^2 s^{-2} [1 rem = 0.01 Sv]
Other Quantities	**Name**	**Symbol**	**Units**
Volume	Liter	L or l	dm^3 = 10^{-3} m^3 = 10^3 cm^3
Length	Ångström	Å	10^{-10} m
Energy	Electron Volt	eV	$1.6021764 \times 10^{-19}$ J
Viscosity		η	Pa s
Diffusion Constant		D	m^2 s^{-1}
Molar Energy			J mol^{-1} = m^2 kg s^{-2} mol^{-1}
Molar Entropy			J K^{-1} mol^{-1} = m^2 kg s^{-2} K^{-1} mol^{-1}
Electric Field Strength		E	V m^{-1} = m kg s^{-3} A^{-1}
Magnetic Field Strength		H	A m^{-1} = N m^{-2} T^{-1} = Pa T^{-1}

Conversion Factors for Important Physical Units

Energy Equivalents

	Joule	Hertz	cm^{-1}	Kelvin	eV
Joule	1	1.5091905 E+33	5.03411762 E+22	7.242964 E+22	6.24150974 E+18
Hertz	6.62606876 E-34	1	3.335640952 E-11	4.7992374 E-11	4.13566727 E-15
cm^{-1}	1.98644544 E-23	2.99792458 E+10	1	1.4387752	1.239841857 E-04
Kelvin	1.3806503 E-23	2.0836644 E+10	0.6950356	1	8.617342 E-05
eV	1.602176462 E-19	2.417989491 E+14	8.06554477 E+03	1.1604506 E+04	1

(based on the Fundamental Constants with $E = mc^2 = hc/\lambda = h\nu = kT$ and 1 eV = (e/C) J

Force Units (SI unit = Newton, cgs unit = dyne), Weight = mass×g_n

	N	p (pond)	kp	dyne
N	1	101.9716	0.1019716	1.0 E+05
p	0.00980665	1	1.00 E-03	980.665
kp	9.80665	1000	1	980665
dyne	1.0 E-05	1.019716 E-03	1.019716 E-06	1

Energy and Work Units (SI unit = Joule, cgs unit: 1 erg = 10^{-7} Joule)

	J = N m	kp m	kWh	kcal	BTU	eV
J	1	0.101972	2.777778 E-07	2.390057 E-04	9.478134 E-04	6.241512 E+18
kp m	9.80665	1	2.724069 E-06	2.343846 E-03	9.294874 E-03	6.120832 E+19
kWh	3.600 E+06	3.670978 E+05	1	860.4207	3412.128	2.246944 E+25
kcal	4184	426.6493	1.162222 E-03	1	3.965651	2.611448 E+22
BTU	1055.06	1.075862 E+02	2.930722 E-04	2.521654 E-01	1	6.585169 E+21
eV	1.602176 E-19	1.633765 E-20	4.450489 E-26	3.829293 E-23	1.518564 E-22	1

Power Units (SI unit = Watt)

	W = J s^{-1}	kW	kpm/s	PS	cal/s	kcal/h
W	1	1.0 E-03	0.1019716	1.341022 E-03	0.2390057	0.8604207
kW	1.0 E+03	1	101.9716	1.341022	239.0057	860.4207
kpm/s	9.80665	9.80665 E-03	1	1.315093 E-02	2.343846	8.437844
PS	745.7	0.7457	76.04024	1	178.2266	641.6157
cal/s	4.184	4.184 E-03	0.4266493	5.610835 E-03	1	3.6
kcal/h	1.162222	1.162222 E-03	0.1185137	1.558565 E-03	0.2777778	1

Pressure Units (SI unit = Pascal)

	Pa=N/m^2	kp/m^2	atm	bar	Torr=mmHg	at=kp/cm^2
Pa=N/m^2	1	0.1019716	9.86923 E-06	1.0 E-05	7.500617 E-03	1.019716 E-05
kp/m^2	9.80665	1	9.67841 E-05	9.80665 E-05	7.355592 E-02	1.0 E-04
atm	1.01325 E+05	1.033227 E+04	1	1.01325	760	1.033227
bar	1.0 E+05	1.019716 E+04	0.9869233	1	750.0617	1.019716
Torr	133.3224	13.59510	1.315789 E-03	1.333224 E-03	1	1.359510 E-03
at=kp/cm^2	9.80665 E+04	1.0 E+04	0.9678411	9.80665 E-01	735.5592	1

Time Units (SI unit = second)

	s	min	h	d	week	year
s	1	1.666667 E-02	2.777778 E-04	1.157407 E-05	1.653439 E-06	3.168874 E-08
min	60	1	1.666667 E-02	6.944444 E-04	9.920635 E-05	1.901324 E-06
h	3600	60	1	4.166667 E-02	5.952381 E-03	1.140795 E-04
d	86400	1440	24	1	1.428571 E-01	2.737907 E-03
week	604800	10080	168	7	1	1.916535 E-02
year	31556952	525949.2	8765.82	365.2425	52.1775	1

Temperature Conversion (SI unit = Kelvin)

	Kelvin (K)	Centigrade (°C)	Fahrenheit (°F)	Rankine (°R)
K	1	$T_C = T_K - 273.15$	$T_F = (9/5)T_K - 459.67$	$T_R = (9/5)T_K$
°C	$T_K = T_C + 273.15$	1	$T_F = (9/5)T_C + 32$	$T_R = (9/5)(T_C + 273.15)$
°F	$T_K = (5/9)(T_F + 459.67)$	$T_C = (5/9)(T_F - 32)$	1	$T_R = T_F + 459.67$
°R	$T_K = (5/9)T_R$	$T_C = (5/9)T_R - 273.15$	$T_F = T_R - 459.67$	1

Conversion Tables

Tubing Diameters and Volumes

Inches (")	No. of Wire Gage*	Millimeters (mm)	Microns (µm)	Volume µl/in	Volume µl/cm
0.001	49	0.025	25	0.013	0.005
0.002	44	0.051	51	0.051	0.020
0.003	40	0.076	76	0.114	0.045
0.004	37	0.102	102	0.206	0.081
0.005	36	0.127	127	0.323	0.127
0.006	34	0.152	152	0.460	0.181
0.007	33	0.178	178	0.632	0.249
0.008	32	0.203	203	0.820	0.323
0.009	31	0.229	229	1.046	0.412
0.010	30	0.254	254	1.288	0.507
0.011	29	0.279	279	1.552	0.611
0.012	28	0.305	305	1.854	0.730
0.013	-	0.330	330	2.172	0.855
0.014	27	0.357	357	2.540	1.000
0.015	26	0.381	381	2.896	1.140
0.016	-	0.406	406	3.287	1.294
0.017	-	0.432	432	3.721	1.465
0.018	25	0.457	457	4.163	1.639
0.019	-	0.483	483	4.650	1.831
0.020	24	0.508	508	5.146	2.026
0.030	21	0.762	762	11.577	4.558
0.040	18	1.016	1016	20.581	8.103
0.050	16	1.270	1270	32.160	12.660

* Gages taken from the American Wire or Brown & Sharpe Gage.

Metric to U. S. Conversion

U. S. to Metric Conversion

Metric	Inches (")	U. S. (")	U. S (")	Metric
1.00 mm	0.039	0.062	1/16	1.59 mm
1.80 mm	0.070	0.125	1/8	3.18 mm
2.00 mm	0.079	0.188	3/16	4.76 mm
3.00 mm	0.118	0.250	1/4	6.35 mm
3.20 mm	0.126	0.313	5/16	7.94 mm
4.00 mm	0.158	0.375	3/8	9.53 mm
4.30 mm	0.170	0.438	7/16	11.11 mm
4.60 mm	0.181	0.500	1/2	12.70 mm
5.00 mm	0.197	0.563	9/16	14.29 mm
6.00 mm	0.236	0.625	5/8	15.86 mm
7.00 mm	0.276	0.688	11/16	17.46 mm
8.00 mm	0.315	0.750	3/4	19.05 mm
9.00 mm	0.355	0.813	13/16	20.64 mm
1.00 cm	0.394	0.875	7/8	22.22 mm
2.00 cm	0.788	0.938	15/16	23.81 mm
3.00 cm	1.182	1.00	1	2.54 cm
4.00 cm	1.576	2.00	2	5.08 cm
5.00 cm	1.970	3.00	3	7.62 cm
6.00 cm	2.364	4.00	4	10.16 cm
7.00 cm	2.758	5.00	5	12.70 cm
8.00 cm	3.152	6.00	6	15.24 cm
9.00 cm	3.546	7.00	7	17.78 cm
10.00 cm	3.940	10.0	10	25.40 cm

Pressure Conversion

PSI	TORR	ATM	BAR
100	5170	6.8	6.7
500	25850	34.0	33.6
1000	51700	68.0	67.2
1500	77550	102.1	100.7
2000	103400	136.1	134.3
2500	129250	170.0	168.0
3000	155100	204.1	201.5
3500	180950	238.0	235.2
4000	206800	272.1	268.6
4500	232650	306.0	302.4
5000	258500	340.2	335.8
5500	284350	374.0	369.6
6000	310200	408.2	402.9
6500	336050	442.0	436.8
7000	361900	476.3	470.1
7500	387750	510.0	504.0
8000	413600	544.0	537.6
8500	439450	578.0	571.2
9000	465300	612.0	604.8
10000	517000	680.4	671.5

Temperature Conversions

Kelvin	Celcius	Fahrenheit
0	-273.15	-459.67
4.2	-268.95	-452.11
10	-263.15	-441.67
20	-253.15	-423.67
30	-243.15	-405.67
40	-233.15	-387.67
50	-223.15	-369.67
60	-213.15	-351.67
70	-203.15	-333.67
77.35	-195.8	-320.44
80	-193.15	-315.67
90	-183.15	-297.67
100	-173.15	-279.67
110	-163.15	-261.67
120	-153.15	-243.67
130	-143.15	-225.67
140	-133.15	-207.67
150	-123.15	-189.67
160	-113.15	-171.67
170	-103.15	-153.67
180	-93.15	-135.67
190	-83.15	-117.67
200	-73.15	-99.67
210	-63.15	-81.67
220	-53.15	-63.67
230	-43.15	-45.67
240	-33.15	-27.67
250	-23.15	-9.67
255.37	-17.78	0
260	-13.15	8.33
270	-3.15	26.33
273.15	0	32
280	6.85	44.33
290	16.85	62.33
300	26.85	80.33
310	36.85	98.33
320	46.85	116.33
330	56.85	134.33
340	66.85	152.33
350	76.85	170.33
360	86.85	188.33
370	96.85	206.33
380	106.85	224.33
390	116.85	242.33
400	126.85	260.33
410	136.85	278.33
420	146.85	296.33
475	201.85	395.33

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