



Bruker Optics



Guide for Infrared Spectroscopy

● Analytical Life Science Process

Innovation with Integrity

Spectroscopy

IR-Spectroscopy & Physical Tables

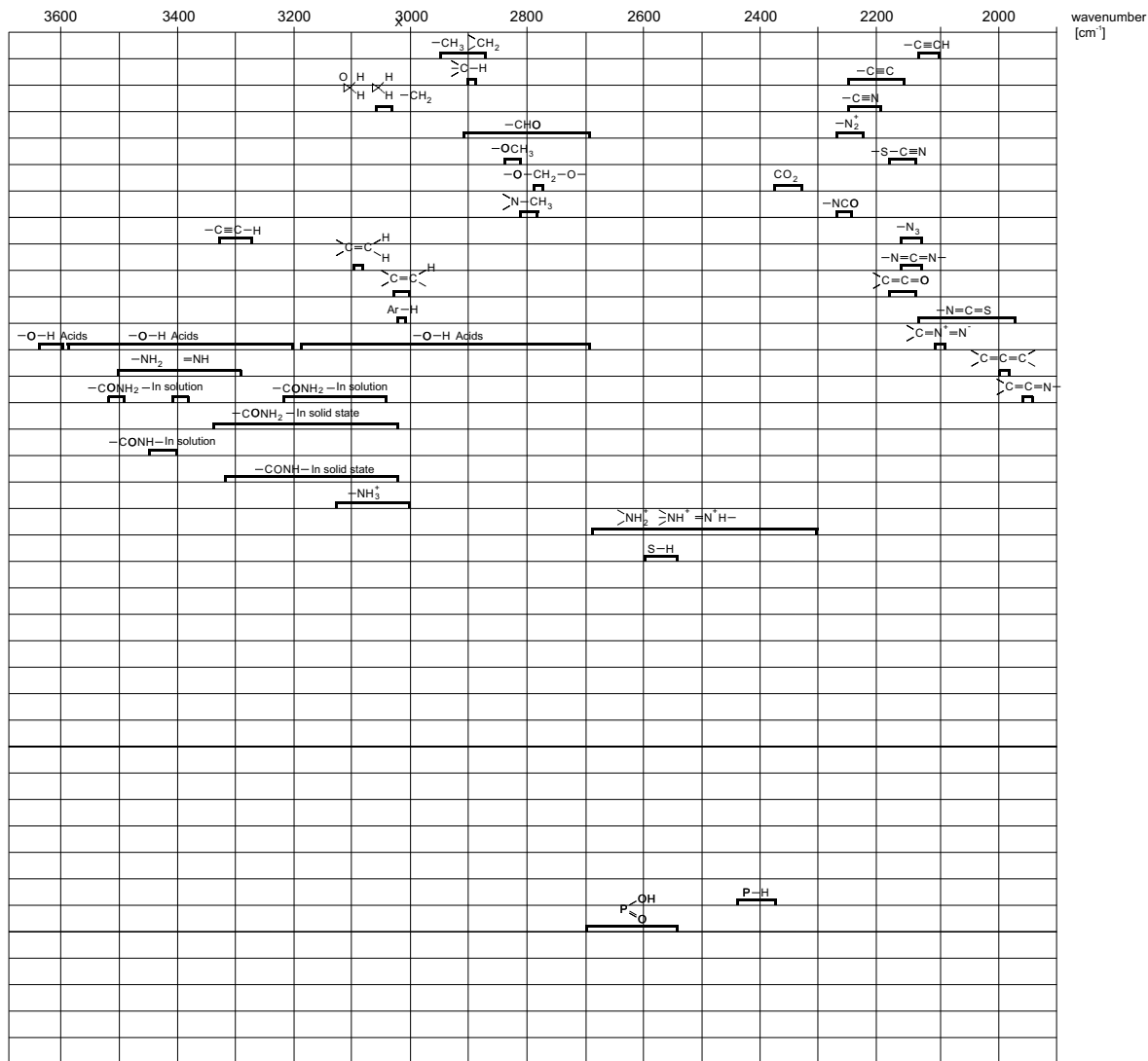
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● IR-Window Material

Material	Transmission Range [cm ⁻¹] ([micrometer])	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 ₂ O 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 ₄ Cl.
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 ₂ SO 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 ₄ OH.
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™ Methylpentene Resin	350-10 (28-1,000)	1.43	~3.3 %		Similar to PE but transparent and more rigid

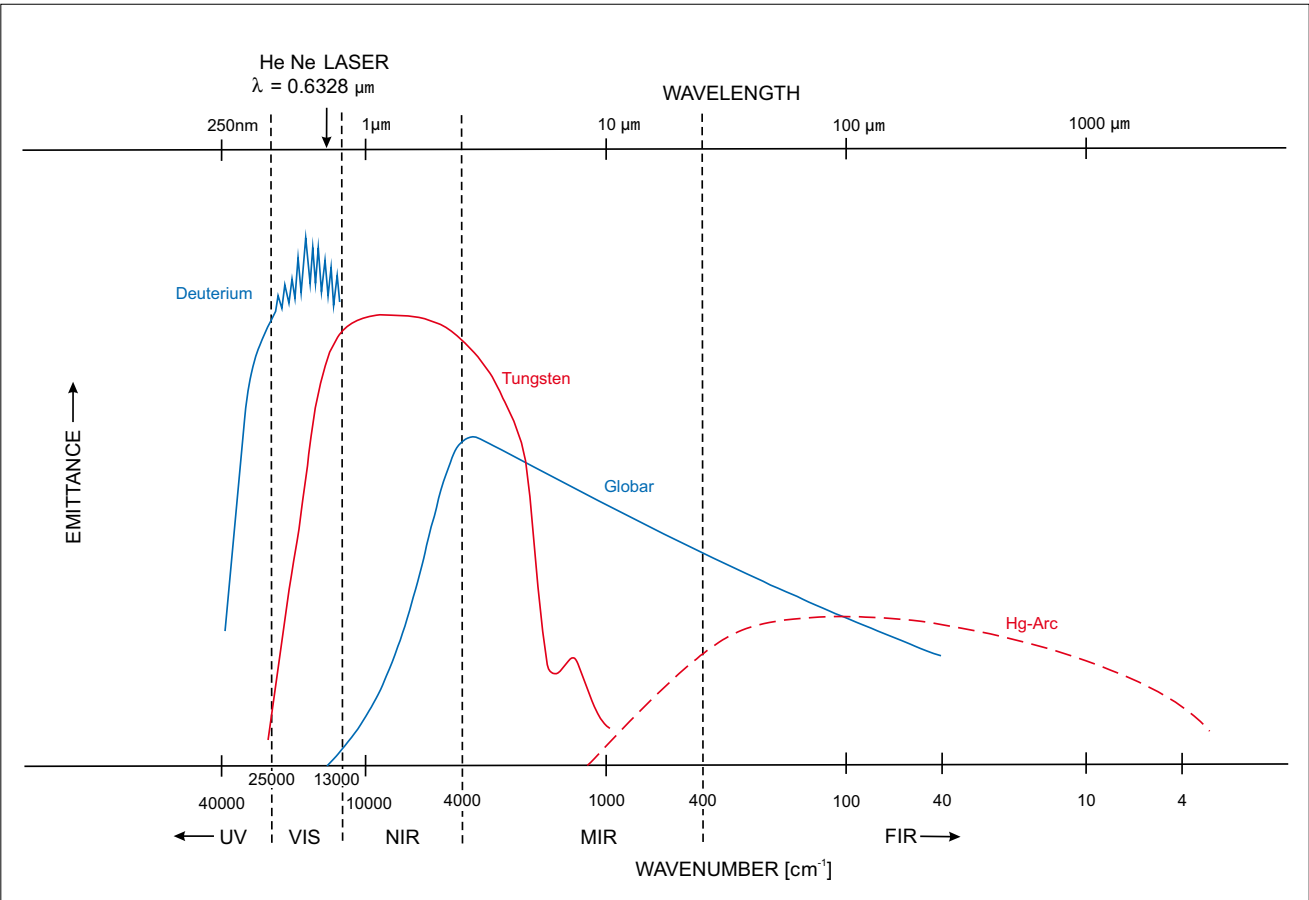
● Infrared Tables



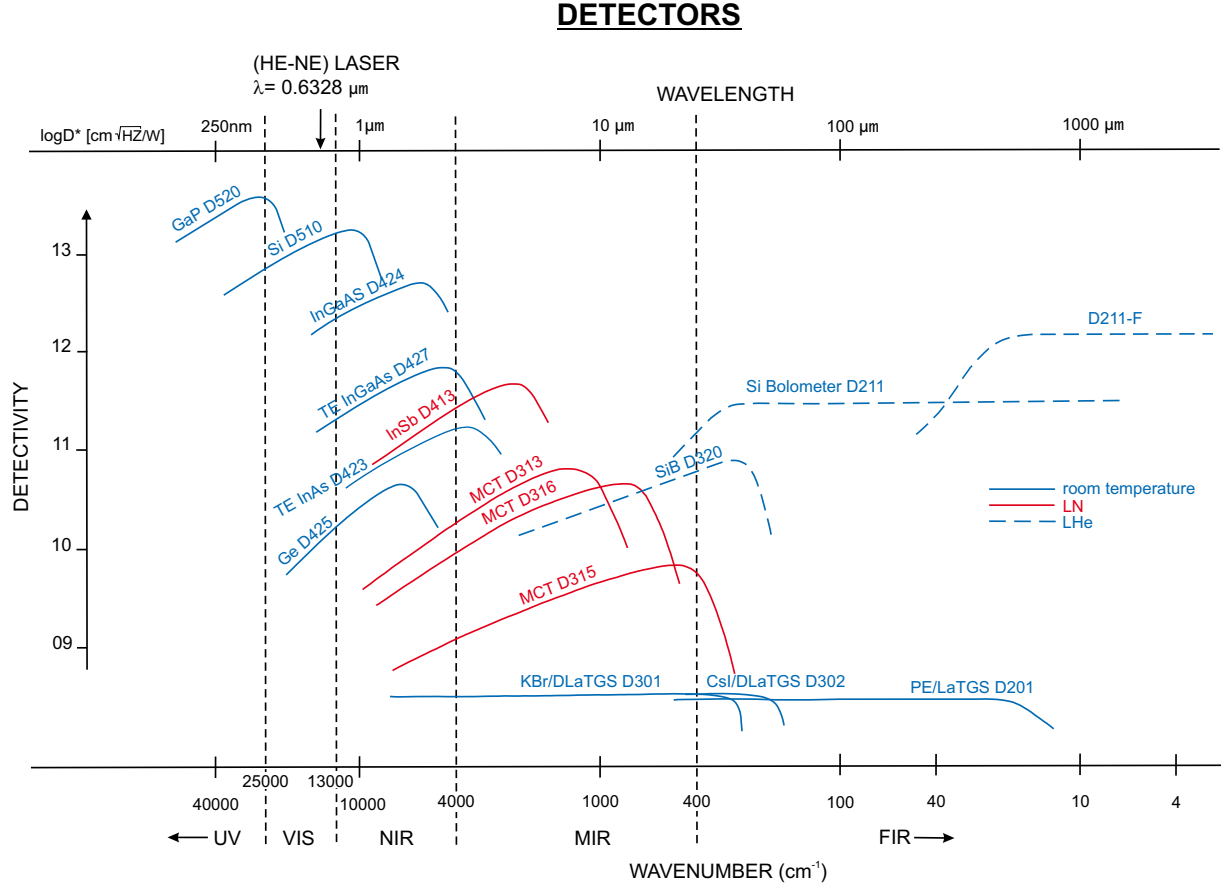
● Infrared Tables

	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	wavenumber [cm ⁻¹]
Anhydrides													
Acid chlorides													
Paracids													
5-Ring lactones													
Lactams													
Imides													
4-Ring lactones													
Urethanes													
5-Ring ketones													
4-Ring ketones													
Saturated esters													
Dienes, Trienes etc.													
Saturated aldehydes													
Saturated ketones													
R-CO-S-R													
Aryl- and α, β-unsaturated esters													
α-Halogen esters and α-ketoesters													
α, β-Unsaturated 5-ring lactones													
β, γ-Unsaturated 5-ring lactones													
Alddehydes, ketones or esters with intramolecular H-bonds													
Aryl- and unsaturated aldehydes													
Aryl- and α, β-unsaturated ketones													
α, β-, α', β', β'-Unsaturated ketones, quinones													
α-Halogen- and α, α'-dihalogen ketones													
1, 2-Diketone													
Saturated carboxylic acids													
Aryl- and α, β-unsaturated carboxylic acids													
α-Halogen carboxylic acids													
Carboxylat ions													
Primary amides in solution													
Primary amides in solid state													
N-monosubst. amides in solution													
N-monosubst. amides in solid state													
N, N-disubst. amides													
Alkanes													
Alkanes													
-OCOCH ₃ -COCH ₃													
-C(CH ₃) ₃													
C(CH ₃) ₂ (Double band)													
-CH=CH- Trans													
C=C-H Alkenes													
-O-H													
C-O													
5 neighbouring aromatic C-H													
4 neighbouring aromatic C-H													
3 neighbouring aromatic C-H													
2 neighbouring aromatic C-H													
Isolated aromatic C-H													
C-NO ₂													
O-NO ₂													
N-NO ₂													
R-CO-S-R													
C=N=O													
-O-N=O													
N-N=O													
-CS-NH-													
>SO													
-SO ₂ N<													
SO ₂ O-													
-SO ₂ N<													
SO ₂ O-													
-													
P-O- Alkyl													
F-O- Alkyl													
P-O- Aryl													
P=O													
P=O													
C-F													
C-Cl													

● Sources

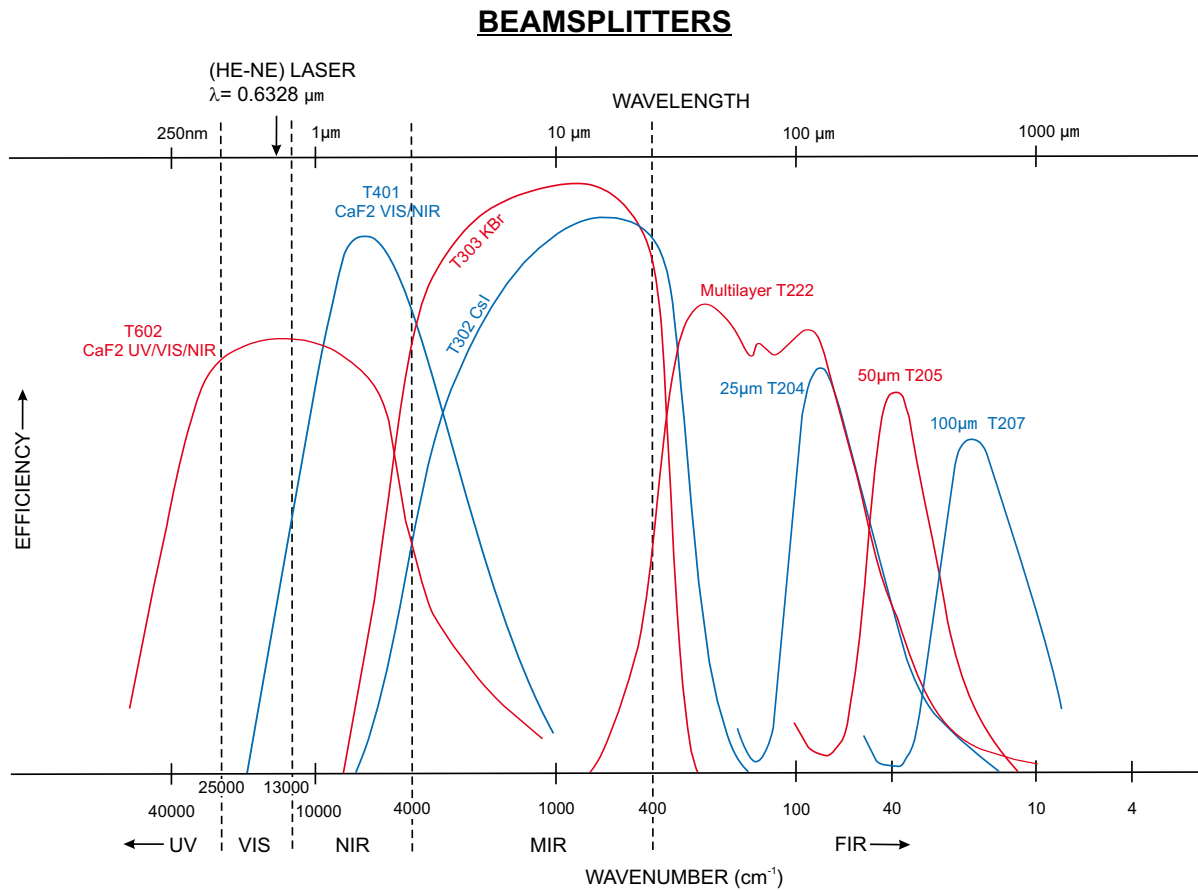


● Detectors



Valid for FT-IR spectrometers

● Beamsplitters



● Conversion Table of Energy and Wavelength Units

Wavenumber [cm ⁻¹]	Wavelength [μm]	Wavelength [nm]	Frequency [GHz]	Electron Volt [eV]	Wavenumber [cm ⁻¹]	Wavelength [μm]	Wavelength [nm]	Frequency [GHz]	Electron Volt [eV]
2.0	5 000.00	5 0000 00	60	.00 025	240.0	41.67	41 667	7 195	.02 976
4.0	2 500.00	2 500 000	120	.00 050	260.0	38.46	38 462	7 795	.03 224
6.0	1 666.67	1 666 667	180	.00 074	280.0	35.71	35 714	8 394	.03 472
8.0	1 250.00	1 250 000	240	.00 099	300.0	33.33	33 333	8 994	.03 720
10.0	1 000.00	1 000 000	300	.00 124	320.0	31.25	31 250	9 593	.03 967
12.0	833.33	833 333	360	.00 149	340.0	29.41	29 412	10 193	.04 215
14.0	714.29	714 286	420	.00 174	360.0	27.78	27 778	10 792	.04 463
16.0	625.00	625 000	480	.00 198	380.0	26.32	26 316	11 392	.04 711
18.0	555.56	555 556	540	.00 223	400.0	25.00	25 000	11 992	.04 959
20.0	500.00	500 000	600	.00 248	500.0	20.00	20 000	14 990	.06 199
22.0	454.55	454 545	660	.00 273	600.0	16.67	16 667	17 987	.07 439
24.0	416.57	416 667	719	.00 298	700.0	14.29	14 286	20 985	.08 679
26.0	384.62	384 615	779	.00 322	800.0	12.50	12 500	23 983	.09 919
28.0	357.14	357 143	839	.00 347	900.0	11.11	11 111	26 981	.11 159
30.0	333.33	333 333	898	.00 372	1 000.0	10.00	10 000	29 979	.12 398
32.0	312.50	312 500	959	.00 397	1 100.0	9.09	9 091	32 977	.13 638
34.0	294.12	294 118	1 019	.00 422	1 200.0	8.33	8 333	35 975	.14 878
36.0	277.78	277 778	1 079	.00 446	1 300.0	7.69	7 692	38 973	.16 118
38.0	263.16	263 158	1 139	.00 471	1 400.0	7.14	7 143	41 971	.17 358
40.0	250.00	250 000	1 199	.00 496	1 500.0	6.67	6 667	44 968	.18 598
50.0	200.00	200 000	1 499	.00 620	1 600.0	6.25	6 250	47 966	.19 837
60.0	166.67	166 667	1 799	.00 744	1 700.0	5.88	5 882	50 964	.21 077
70.0	142.86	142 857	2 099	.00 868	1 800.0	5.56	5 556	53 962	.22 317
80.0	125.00	125 000	2 398	.00 992	1 900.0	5.26	5 263	56 960	.23 557
90.0	111.11	111 111	2 698	.01 116	2 000.0	5.00	5 000	59 958	.24 797
100.0	100.00	100 000	2 988	.01 240	2 200.0	4.55	4 545	65 954	.27 276
110.0	90.91	90 909	3 298	.01 364	2 400.0	4.17	4 167	71 950	.29 756
120.0	83.33	83 333	3 597	.01 488	2 600.0	3.85	3 846	77 945	.32 236
130.0	76.92	76 923	3 897	.01 612	2 800.0	3.57	3 571	83 941	.34 716
140.0	71.43	71 429	4 197	.01 736	3 000.0	3.33	3 333	89 937	.37 195
150.0	66.67	66 667	4 497	.01 860	3 200.0	3.13	3 125	95 933	.39 675
160.0	62.50	62 500	4 797	.01 984	3 400.0	2.94	2 941	101 929	.42 155
170.0	58.85	58 824	5 096	.02 108	3 600.0	2.78	2 778	107 924	.44 634
180.0	55.56	55 556	5 396	.02 232	3 800.0	2.63	2 632	113 920	.47 114
190.0	52.63	52 632	5 696	.02 356	4 000.0	2.50	2 500	119 916	.49 594
200.0	50.00	50 000	5 996	.02 480	5 000.0	2.00	2 000	149 895	.61 992
220.0	45.45	45 455	6 595	.02 728	6 000.0	1.67	1 667	179 874	.74 390

● Conversion Table of Energy and Wavelength Units

Wavenumber [cm ⁻¹]	Wavelength [μm]	Wavelength [nm]	Frequency [GHz]	Electron Volt [eV]
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
50 000.0	.20	200	1 498 950	6.19 921



● Conversion Table of Transmittance and Absorbance Units

Transmittance [%]	Absorbance	Tansmittance [%]	Absorbance
1.0	2.000	51.0	.292
2.0	1.699	52.0	.284
3.0	1.523	53.0	.276
4.0	1.398	54.0	.268
5.0	1.301	55.0	.260
6.0	1.222	56.0	.265
7.0	1.155	57.0	.244
8.0	1.097	58.0	.237
9.0	1.046	59.0	.229
10.0	1.000	60.0	.222
11.0	.959	61.0	.215
12.0	.921	62.0	.208
13.0	.886	63.0	.201
14.0	.854	64.0	.194
15.0	.824	65.0	.187
16.0	.796	66.0	.180
17.0	.770	67.0	.174
18.0	.745	68.0	.167
19.0	.721	69.0	.161
20.0	.699	70.0	.155
21.0	.678	71.0	.149
22.0	.658	72.0	.143
23.0	.638	73.0	.137
24.0	.620	74.0	.131
25.0	.602	75.0	.125
26.0	.585	76.0	.119
27.0	.569	77.0	.114
28.0	.553	78.0	.108
29.0	.538	79.0	.102
30.0	.523	80.0	.097
31.0	.509	81.0	.092
32.0	.495	82.0	.086
33.0	.481	83.0	.081
34.0	.469	84.0	.076
35.0	.456	85.0	.071
36.0	.444	86.0	.066
37.0	.432	87.0	.060
38.0	.420	88.0	.056
39.0	.409	89.0	.051
40.0	.398	90.0	.046
41.0	.387	91.0	.041
42.0	.377	92.0	.036
43.0	.367	93.0	.032
44.0	.357	94.0	.027
45.0	.347	95.0	.022
46.0	.337	96.0	.018
47.0	.328	97.0	.013
48.0	.319	98.0	.009
49.0	.310	99.0	.004
50.0	.301	100.0	.000

● Physical Tables: 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	$2\pi \text{ rad} = 360^\circ$, $1 \text{ rad} = 57.2957795^\circ$ rad s^{-1} [$1 \text{ Hz} = 2\pi \text{ rad s}^{-1}$]
Solid Angle	Steradian	sr	$4\pi \text{ sr} = \text{sphere}$
Force	Newton	N	m kg s^{-2}
Pressure, Stress	Pascal	Pa	$\text{N m}^{-2} = \text{m}^{-1} \text{ kg s}^{-2}$ [$1 \text{ bar} = 10^5 \text{ Pa}$]
Energy, Work, Heat	Joule	J	$\text{N m} = \text{m}^2 \text{ kg s}^{-2}$
Power, radiant flux	Watt	W	$\text{J s}^{-1} = \text{m}^2 \text{ kg s}^{-3}$
Electric Charge	Coulomb	C	A s
Electric potential, emf	Volt	V	$\text{J C}^{-1} = \text{m}^2 \text{ kg s}^{-3} \text{ A}^{-1}$
Electrical Resistance	Ohm	Ω	$\text{V A}^{-1} = \text{m}^2 \text{ kg s}^{-3} \text{ A}^{-2}$
Electrical Conductance	Siemens	S	$\Omega^{-1} = \text{m}^{-2} \text{ kg}^{-1} \text{ s}^3 \text{ A}^2$
Electrical Capacitance	Farad	F	$\text{C V}^{-1} = \text{m}^{-2} \text{ kg}^{-1} \text{ s}^4 \text{ A}^2$
Magnetic Flux	Weber	Wb	$\text{V s} = \text{m}^2 \text{ kg s}^{-2} \text{ A}^{-1}$
Magnetic Flux Density	Tesla	T	$\text{Wb m}^{-2} = \text{V s m}^{-2} = \text{kg s}^{-2} \text{ A}^{-1}$
Inductance	Henry	H	$\text{V A}^{-1} \text{ s} = \text{m}^2 \text{ kg s}^{-2} \text{ A}^{-2}$
Celsius Temperature	$^\circ\text{C}$	K	$^\circ\text{C} = \text{Temp. (K)} - 273.15$
Light Flux	Lumen	lm	cd sr
Illuminance	Lux	lx	cd sr m^{-2}
Activity (radioactive decay)	Becquerel	Bq	s^{-1} [$1 \text{ Curie (Ci)} = 37 \text{ GBq}$]
Absorbed Dose	Gray	Gy	$\text{J kg}^{-1} = \text{m}^2 \text{ s}^{-2}$ [$1 \text{ rad} = 0.01 \text{ Gy}$]
Equivalent Dose, Energy Dose	Sievert	Sv	$\text{J kg}^{-1} = \text{m}^2 \text{ s}^{-2}$ [$1 \text{ rem} = 0.01 \text{ Sv}$]
Other Quantities	Name	Symbol	Units
Volume	Liter	L or l	$\text{dm}^3 = 10^{-3} \text{ m}^3 = 10^3 \text{ cm}^3$
Length	Ångström	Å	10^{-10} m
Energy	Electron Volt	eV	$1.6021764 \times 10^{-19} \text{ J}$
Viscosity		η	Pa s
Diffusion Constant		D	$\text{m}^2 \text{ s}^{-1}$
Molar Energy			$\text{J mol}^{-1} = \text{m}^2 \text{ kg s}^{-2} \text{ mol}^{-1}$
Molar Entropy			$\text{J K}^{-1} \text{ mol}^{-1} = \text{m}^2 \text{ kg s}^{-2} \text{ K}^{-1} \text{ mol}^{-1}$
Electric Field Strength		E	$\text{V m}^{-1} = \text{m kg s}^{-3} \text{ A}^{-1}$
Magnetic Field Strength		H	$\text{A m}^{-1} = \text{N m}^{-2} \text{ T}^{-1} = \text{Pa T}^{-1}$

● **Vibrational Spectroscopy:**

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

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 ₂ S
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 ₂ H ₆	H-Se	3.51	0.93	H ₂ Se
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 ₂ CCH ₂
Br-Br	2.36	1.1	Br ₂	C-C	7.6	1.7	C ₆ H ₆
Rb-Rb	0.08	0.2	Rb ₂	C-C	4.4	1.1	H ₃ CCH 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 ₂ O	C-S	7.67	2.0	CS ₂

● **Vibrational Spectroscopy :**

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

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 ₄ CO	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) ₃
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 ₂ ⁴
C-I	1.69	0.79	Cl 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	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-N-N ⁻	O-Ti	7.19	2.4	TiO
N-O	25.07	3.1	N-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) ₃ Si) ₂ NH	O-Se	6.45	1.5	SeO
N-S	12.54	2.5	NSF ₃	O-Mo	3.05	1.2	Ba ₂ CaMoO ₆ (solid)
N-S	8.3	1.9	HNSO	O-Ru	6.70	2.2	RuO ₄
N-S	3.1	0.87	H ₃ N-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 ·H ₂ O (polymer)

● 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 $E = mc^2 = hc/\lambda = hv = kT$ and $1 \text{ eV} = (e/C) \text{ J}$)

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-01	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	1.019716E+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	9.800665 E-01	735.5592	1

● Conversion Factors for Important Physical Units

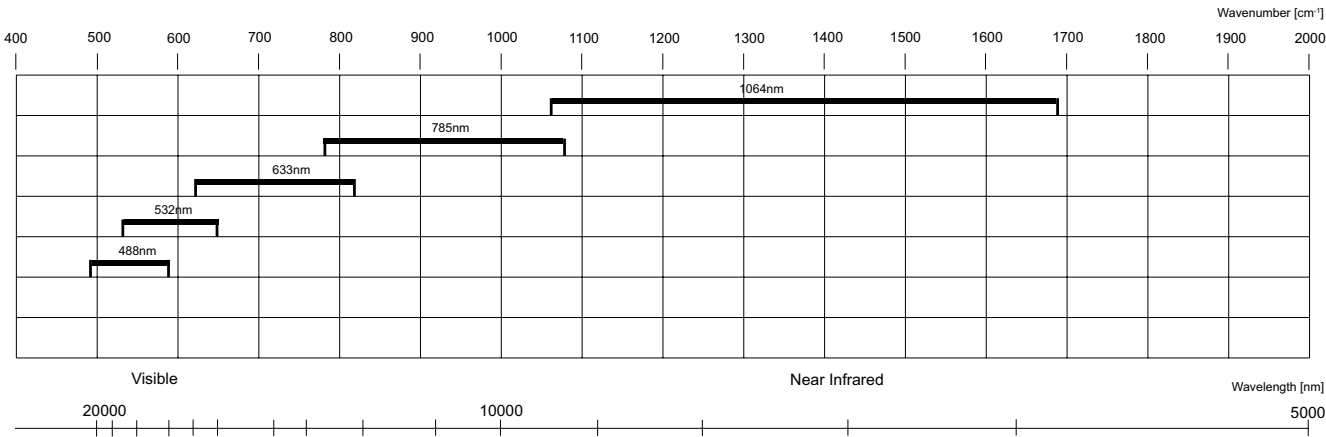
Time Units (SI unit = second)

	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	$T_K = (9/5)T_R$	$T_C = (5/9)T_R - 273.15$	$T_F = T_R - 459.67$	1

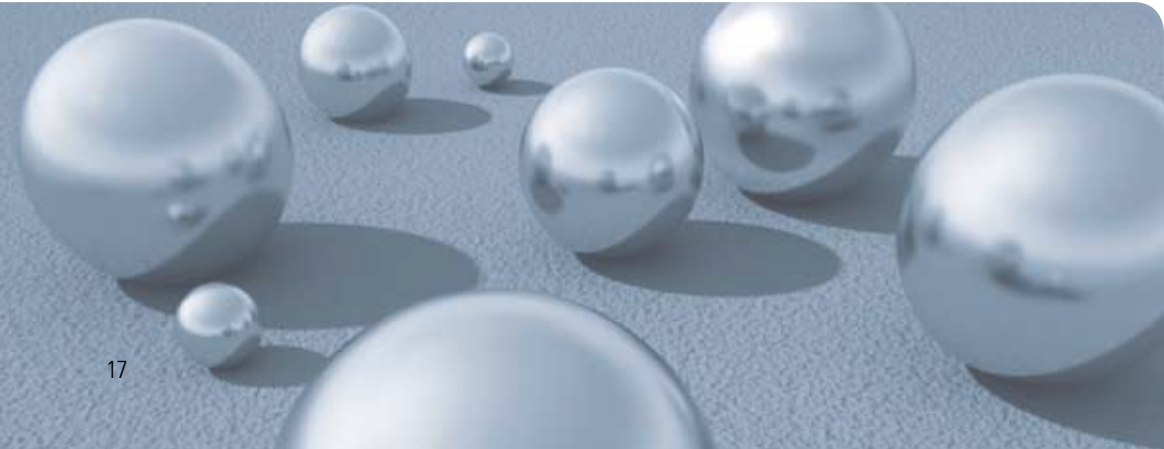
● Stokes Shifts (0-3500cm⁻¹) of Various Raman Laser Sources



● Conversion Tables

Metric to U. S. Conversion U. S. to Metric Conversion

Metric	Inch (")	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



● Conversion Tables

Tubing Diameters and Volumes

Inch (")	No. of Wire Gage*	Millimeter (mm)	Micron (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.

● Conversion Tables

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

Kelvin	Celcius	Fahrenheit
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	32.00
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

● Conversion Tables

Pressure Conversion

PSI	Torr	ATM	bar/10 ³ hPa
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



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