HANDBOOK OF INFRARED STANDARDS

With Spectral Maps and Transition Assignments between 3 and 2600 μm

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(c) Frequency markers based on $^{12}C^{16}O_2$ lasers locked to SF_6 saturation peaks are given in Tables 3–8.

Saturated absorption measurements on some 2-0 band lines of $^{12}C^{16}O$ are given in Table 9. Tables 10 and 11 summarize the recent work on the 9.4 μm and 10.4 μm CO_2 laser lines using an intracavity saturated fluorescence technique.

In 1985, Chardonnet *et al.*[4] recorded "super-narrow" saturation resonances (HWHM = 2.1 kHz) of CO_2 and made measurements on three of the 10.4 μm CO_2 band laser lines. The P(12) line of this band was found to be −25 330.7 kHz from the $^{192}OsO_4$ line[5] at 28 516 051 989.3 kHz, and its P(14) was located −3219.5 kHz from the $^{192}OsO_4$ line[3] at 28 464 676 938.5 kHz. Also, the R(10) line was located +15 254.2 kHz from the $^{192}OsO_4$ line[6] at 29 054 057 446.660 kHz. These measurements led to the following absolute frequencies for these three CO_2 lines: 28 516 026 658.6 (1.4) kHz for P(12); 28 464 673 719.0 (1) kHz for P(14); and 29 054 072 700.86 (0.2) kHz for R(10). The entries in parentheses give uncertainties in the last digits of the frequencies. The corresponding values for these lines from Table 11 are 28 516 026 657.7; 28 464 673 719.0; and 29 054 072 699.5 kHz, and the agreement between the two sets of data is excellent.

II. HETERODYNE FREQUENCY DATA

Heterodyne frequency measurements for lines in the spectra of the diatomic molecules CO and DBr, the linear triatomic molecules OCS and N_2O and the pyramidal molecule NH_3 are summarized in Tables 12–25. Most of the lines are vibration-rotation transitions except for the ones in Tables 14 and 15, which give pure rotational transitions of $^{12}C^{16}O$ and HF.

III. WAVENUMBER COVERAGE AND SOURCES OF THE SPECTRAL MAPS AND CORRESPONDING WAVENUMBER DATA IN THIS HANDBOOK

It is believed that all wavenumbers accompanying the spectral maps have an absolute accuracy of at least 0.001 cm^{-1}, whereas wavenumber differences between neighboring lines have a much higher accuracy of 0.0001 cm^{-1} or better.

[4] Ch. Chardonnet, A. van Lerberghe, and Ch. J. Bordé, *Ninth Colloquium on High Resolution Molecular Spectroscopy,* Riccione, Italy, September 16–20, 1985, and *Opt. Commun.* (in press); Ch. J. Bordé, Ch. Bréant, Ch. Chardonnet, A. van Lerberghe, and Ch. Salomon, *in* "Laser Spectroscopy" (T. W. Hänsch and Y. R. Shen, eds.), Vol. VII, Springer-Verlag, Berlin (1985).

[5] A. Clairon, A. van Lerberghe, Ch. Bréant, Ch. Salomon, G. Camy, and Ch. J. Bordé, *J. Phys. Colloq.* (Paris) **42,** Suppl. to No. 12, **C8,** 127–135 (1981).

[6] A. Clairon, B. Dahmani, A. Filimon, and J. Rutman, *IEEE Trans. Instrum. Meas.*, **IM-34**(2), 265–268 (1985).

TABLE 1. Absolute Frequencies[1] of Several OsO_4 Lines

CO_2 coinciding laser line	$\nu_{OsO_4} - \nu_{CO_2}$ MHz	Measured frequency distance in kHz to OsO_4 line coinciding with P(14) CO_2 line	OsO_4 frequency kHz	Wavenumber vac. cm^{-1}
P(22)	-12.1	-212 747 424.2(0.9)	28 251 929 514.3	942.382 930 60
P(20)	+9.3	-158 442 817.9(1.4)	28 306 234 120.6	944.194 337 29
P(18)	-3.8	-104 906 981.6(1.4)	28 359 769 956.9	945.980 100 57
P(16)	+33.4	-52 053 827.8(1.0)	28 412 623 110.7	947.743 092 01
P(14)	+3.2	Absolute Reference[2]	28 464 676 938.5	949.479 420 81
P(12)	+25.4	+51 375 050.8(1.0)	28 516 051 989.3	951.193 108 04
P(10)	-18.8	+101 953 433.3(1.4)	28 566 630 371.9	952.880 221 29
P(8)	+11.9	+151 876 690.7(1.4)	28 616 553 629.2	954.545 481 90
P(4)	-25.3	+249 435 486.0(0.9)	28 714 112 424.5	957.799 693 03
R(4)	-15.7	+458 353 737.9(2.3)	28 923 030 676.4	964.768 455 80
R(6)	-33.9	+502 746 255.5(2.0)	28 967 423 194.0	966.249 230 79
R(8)	+4.4	+546 460 434.1(1.7)	29 011 137 372.6	967.707 378 84
R(10)	-15.2	+589 380 509.4(1.4)	29 054 057 447.9	969.139 038 44
R(12)	+0.6	+631 598 015.4(1.7)	29 096 274 953.9	970.547 262 86
R(14)	+10.9	+673 070 096.4(2.0)	29 137 747 034.9	971.930 622 58
R(16)	+13.2	+713 791 977.3(2.3)	29 178 468 915.8	973.288 958 32
R(18)	+19.4	+753 773 091.9(2.5)	29 218 450 030.4	974.622 584 75
R(20)	-24.7	+792 956 884.9(2.7)	29 257 633 823.4	975.929 615 39
R(22)	+10.0	+831 469 420.0(2.8)	29 296 146 358.5	977.214 255 29
R(26)	-15.5	+906 137 139.9(3.0)	29 370 814 078.5	979.704 902 33

[1] A. Clairon, A. van Lerberghe, Ch. Bréant, Ch. Salomon, G. Camy, and Ch. J. Bordé, *J. Phys. Colloq.* (Paris) **42,** Suppl. to No. 12, **C8,** 127–135 (1981).

[2] Yu. S. Domnin, N. B. Roshelyaevskii, V. M. Tatarenkov, P. S. Shumyatskii, O. N. Kompanets, A. R. Kukudzhanov, V. S. Letokhov, and E. L. Mikhailov, *JETP Lett. (Engl. Transl.),* **IM34,** 249–252 (1979).

[1] A. Clairon, A. van Lerberghe, Ch. Bréant, Ch. Salomon, G. Camy, and Ch. J. Bordé, *J. Phys. Colloq.* (Paris) **42,** Suppl. to No. 12, **C8,** 127–135 (1981).
[2] Yu. S. Domnin, N. B. Roshelyaevskii, V. M. Tatarenkov, P. S. Shumyatskii, O. N. Kompanets, A. R. Kukudzhanov, V. S. Letokhov, and E. L. Mikhailov, *JETP Lett. (Engl. Transl.),* **IM34,** 249–252 (1979).

TABLE 2. Absolute Frequencies[1] of Several Assigned OsO_4 Lines

OsO_4 Line Assignment			Coincident CO_2 laser line	OsO_4 Frequency kHz	OsO_4 Wavenumber vac. cm^{-1}
P(49)	A2(3)	189 Os [a]	P(14)	28 464 739 406.5	949.481 504 52
P(49)	A1(3)	189 Os [a]	P(14)	28 464 742 149.9	949.481 596 03
P(46)	A2(2)	192 Os	P(14)	28 464 788 928.8	949.483 156 40
P(39)	A2(3)	192 Os	P(12)	28 516 051 989.3	951.193 108 04
P(39)	A1(2)	192 Os	P(12)	28 516 052 446.5	951.193 123 29
P(30)	A2(1)	188 Os	P(8)	28 616 553 629.2	954.545 481 90
R(26)	A1(0)	189 Os [a]	R(8)	29 011 181 447.6	967.708 849 02
R(36)	A1(0)	192 Os	R(10)	29 054 231 145.4	969.144 832 37
R(40)	A1(1)	190 Os	R(12)	29 096 404 958.7	970.551 599 36
R(49)	A1(2)	187 Os [a]	R(16)	29 178 468 915.8	973.288 958 32
R(55)	A2(2)	192 Os	R(16)	29 178 571 255.0	973.292 371 98

[1] Ch. J. Bordé (private communication, 1986).
The frequency and wavenumber accuracies are respectively of the order of 1 kHz and 3.4×10^{-8} cm^{-1}.
The measurements were made relative to lines given in Table 1.
[a] Center of resolved hyperfine structure.

TABLE 3. Absolute Frequencies[1] of Several SF_6 Lines Measured Relative to the SF_6 line[2] at 28 251 957 355 kHz: These Frequencies Are Near the Laser Line P(22) of the 10.4 μm $^{12}C^{16}O_2$ Band

Identification	$\nu - \nu_{Ref}$ MHz	Frequency MHz	Wavenumber vac. cm^{-1}
P(83) F_1^{13}	-208.24	28 251 749.115	942.376 913 13
P(82) F_2^{10}	-103.136	28 251 854.219	942.380 419 02
P(82) F_1^{10}	-101.01	28 251 856.345	942.380 489 94
P(81) $F_1^{8} + F_2^{7}$	42.25	28 251 999.605	942.385 268 58
P(84) A_2^{1}	48.26	28 252 005.615	942.385 469 05
P(84) F_2^{3}	48.54	28 252 005.895	942.385 478 39
P(84) F_1^{3}	48.81	28 252 006.165	942.385 487 40
P(84) A_1^{1}	49.095	28 252 006.450	942.385 496 90
P(83) F_2^{14}	99.01	28 252 056.365	942.387 161 89
P(83) E^{9}	178.7	28 252 136.055	942.389 820 06

[1] J. Bordé and Ch. J. Bordé, *Chem. Phys.* **71,** 417–441 (1982).
[2] A. Clairon, A. van Lerberghe, Ch. Salomon, M. Ouhayoun, and Ch. J. Bordé, *Opt. Comm.* **35,** 368–372 (1980).

TABLE 4. Absolute Frequencies[1] of Several SF_6 Lines Measured Relative to the SF_6 Line[2] at 28 306 252 637 kHz: These Frequencies Are Near the Laser Line P(20) of the 10.4 μm $^{12}C^{16}O_2$ Band

Identification	$\nu_{SF_6} - \nu_{P(59)A_2^3}$ MHz	Frequency MHz	Wavenumber vac. cm^{-1}
$P(57)F_1^3 + F_2^3$	-253.572	28 305 999.065	944.186 496 68
$P(58)F_2^9 + F_1^8$	-224.99	28 306 027.647	944.187 450 07
$P(59)F_1^9$	-168.941	28 306 083.696	944.189 319 67
$P(60)F_1^1$	-102.892	28 306 149.745	944.191 522 82
$P(60)E^0$	-102.783	28 306 149.854	944.191 526 46
$P(60)F_2^1$	-102.674	28 306 149.963	944.191 530 10
$P(59)F_2^9$	-100.748	28 306 151.889	944.191 594 34
$P(59)A_2^3$	0.000	28 306 252.637	944.194 954 93
$P(55)F_2^0 + F_1^0$	60.328	28 306 312.965	944.196 967 26
$P(56)A_2^3 + E^8 + F_2^{12}$	100.13	28 306 352.767	944.198 294 91
$P(59)F_2^{10}$	198.525	28 306 451.162	944.201 577 01

[1] Ch. J. Bordé, *Rev. Cethedec-Ondes et Signal NS 83-1,* 1–118 (1983).
[2] A. Clairon, A. van Lerberghe, Ch. Salomon, M. Ouhayoun, and Ch. J. Bordé, *Opt. Comm.*, **35,** 368–372 (1980).

TABLE 5. Absolute Frequencies[1] of Several SF_6 Lines Measured Relative to the SF_6 P(33) A_2^1 line[2] at 28 359 780 517 MHz: These Frequencies Are Near the Laser Line P(18) of the 10.4 μm $^{12}C^{16}O_2$ Band

Identification	$\nu - \nu_{Ref}$ MHz	Frequency MHz	Wavenumber vac. cm^{-1}
P(33) F_1^5	-132.656	28 359 647.861	945.976 027 89
P(32) $F_2^7 + F_1^6$	-124.106	28 359 656.411	945.976 313 09
P(33) F_2^4	-91.302	28 359 689.215	945.977 407 31
P(33) A_2^1	-0-	28 359 780.517	945.980 452 82
P(33) F_2^5	101.423	28 359 881.94	945.983 835 92
P(33) E^3	134.845	28 359 915.362	945.984 950 76
P(33) F_1^6	180.065	28 359 960.582	945.986 459 14

[1] Ch. J. Bordé, M. Ouhayoun, A. van Lerberghe, C. Salomon, S. Avrillier, C. D. Cantrell, and J. Bordé, *in* "Laser Spectroscopy" (H. Walther and K. W. Rothe, eds.), Vol. IV, p. 142, Springer-Verlag, New York (1979).

[2] B. Bobin, Ch. J. Bordé, J. Bordé, and Ch. Bréant (to be published).

TABLE 6. Absolute Frequencies[1,2] of Several SF_6 Lines Measured Relative to the SF_6 Q(38) E° Line[2] at 28 412 582 469 kHz: These Frequencies Are in the Spectral Region of the Laser Line P(16) of the 10.4 μm $^{12}C^{16}O_2$ Band

Identification	$\nu_{SF_6} - \nu_{Q(38)E^\circ}$ MHz	Frequency MHz	Wavenumber vac. cm^{-1}
$Q(55)F_2^6$	-242.20	28 412 340.269	947.733 657 43
$Q(55)F_1^6$	-234.82	28 412 347.649	947.733 903 60
$Q(46)F_1^3$	-205.982	28 412 376.487	947.734 865 53
$Q(49)F_1^7$	-199.746	28 412 382.723	947.735 073 54
$Q(47)F_1^7$	-185.429	28 412 397.040	947.735 551 11
$Q(49)E^4$	-151.798	28 412 430.671	947.736 672 92
$Q(54)A_2^2$	-139.62	28 412 442.849	947.737 079 13
$Q(54)F_2^7$	-129.485	28 412 452.984	947.737 417 20
$Q(54)E^4$	-124.55	28 412 457.919	947.737 581 81
$Q(41)F_1^9$	-115.031	28 412 467.438	947.737 899 33
$Q(41)E^5$	-109.595	28 412 472.874	947.738 080 66
$Q(48)F_1^4$	-107.868	28 412 474.601	947.738 138 26
$Q(41)F_2^8$	-104.113	28 412 478.356	947.738 263 52
$Q(45)A_2^2$	- 56.057	28 412 526.412	947.739 866 49
$Q(53)F_2^6$	- 22.85	28 412 559.619	947.740 974 16
$Q(53)F_1^6$	- 9.38	28 412 573.089	947.741 423 47
$Q(38)F_2^0$	- 0.506	28 412 581.963	947.741 719 47

[1] Ch. J. Bordé, *Rev. Céthedec-Ondes et Signal NS 83-1,* 1–118 (1983).
[2] A. Clairon, A. van Lerberghe, Ch. Salomon, M. Ouhayoun, and Ch. J. Bordé, *Opt. Comm.* **35,** 368–372 (1980).

TABLE 6. *(Continued)*

Identification	$\nu_{SF_6} - \nu_{Q(38)E^0}$ MHz	Frequency MHz	Wavenumber vac. cm^{-1}
$Q(38)E^0$	0.000	28 412 582.469	947.741 736 35
$Q(38)F_1^0$	0.507	28 412 582.976	947.741 753 26
$Q(43)F_1^8$	16.66	28 412 599.129	947.742 292 07
$Q(45)F_2^7$	19.756	28 412 602.225	947.742 395 34
$Q(48)F_2^5$	43.54	28 412 626.009	947.743 188 69
$Q(43)E^5$	43.933	28 412 626.402	947.743 201 80
$Q(43)F_2^8$	79.863	28 412 662.332	947.744 400 29
$Q(47)E^4$	80.093	28 412 662.562	947.744 407 97
$Q(52)E^4$	92.97	28 412 675.439	947.744 837 50
$Q(52)F_1^6$	101.903	28 412 684.372	947.745 135 47
$Q(46)A_1^1$	103.254	28 412 685.723	947.745 180 53
$Q(45)F_1^8$	106.854	28 412 689.323	947.745 300 62
$Q(52)A_1^2$	119.025	28 412 701.494	947.745 706 59
$Q(47)F_2^7$	154.333	28 412 736.802	947.746 884 35
$Q(51)F_2^6$	212.92	28 412 795.389	947.748 838 59
$P(4)A_1^0$	228.158	28 412 810.627	947.749 346 88
$Q(51)F_1^6$	235.499	28 412 817.968	947.479 591 75
$P(4)F_1^0$	245.073	28 412 827.542	947.749 911 11
? F_2	245.16	28 412 827.629	947.749 914 01
$Q(40)A_1^0$	254.091	28 412 836.560	947.750 211 91
$P(4)E^0$	257.121	28 412 839.590	947.750 312 98
$Q(45)A_1^2$	258.162	28 412 840.631	947.750 347 71
$Q(40)F_1^1$	260.27	28 412 842.739	947.750 418 02

TABLE 7. Absolute Frequencies[1] of Several SF_6 Lines Measured Relative to the OsO_4 line[2] at 28 464 676 938.5 kHz: These Frequencies Are Near the Laser Line P(14) of the 10.4 μm $^{12}C^{16}O_2$ Band

Identification	$\nu - \nu_{Ref}$ MHz	Frequency MHz	Wavenumber vac. cm^{-1}
R(28) E^1	-170.02	28 464 506.918	949.473 749 5
R(28) F_2^2	-147.38	28 464 529.558	949.474 504 7
R(28) A_2^0	14.37	28 464 691.308	949.479 900 1
R(28) F_2^1	35.48	28 464 712.418	949.480 604 3
R(28) F_1^1	51.5	28 464 728.438	949.481 138 6
R(28) A_1^0	65	28 464 741.938	949.481 589 0
R(29) $F_1^2 + F_2^1$	181.25	28 464 858.188	949.485 466 6

[1] Ch. J. Bordé, *Rev. Cethedec-Ondes et Signal NS 83-1,* 1–118 (1983).

[2] Yu S. Domnin, N. B. Roshelyaevskii, V. M. Tatarenkov, P. S. Shumyatskii, O. N. Kompanets, A. R. Kukudzhanov, V. S. Letokhov, and E. L. Mikhailov, *JETP Lett. (Engl. Transl.),* **IM34,** 249–252 (1979).

TABLE 8. Absolute Frequencies[1] of Several SF_6 Lines Measured Relative to the OsO_4 P(39) A_2^3 line[2,3] at 28 516 051 989 kHz: These Frequencies Are Near the Laser Line P(12) of the 10.4 μm $^{12}C^{16}O_2$ Band

Identification	$\nu - \nu_{Ref}$ MHz	Frequency MHz	Wavenumber vac. cm^{-1}
R(74) E^8 $F_2^{12}A_2^3$	-194.3	28 515 857.689	951.186 626 88
R(89) A_1^0 E^0 F_1^1	-142.6	28 515 909.389	951.188 351 41
R(73) E^4 F_1^7 A_1^2	-138.6	28 515 913.389	951.188 484 84
R(66) A_1^0 F_1^0 F_2^0 A_2^0	-48.36	28 516 003.629	951.191 494 92
R(83) E^1 F_1^2 A_1^0	0.04	28 516 052.029	951.193 109 37
R(77) F_1^5 F_2^4	28.48	28 516 080.469	951.194 058 02
R(94) E^{15} $F_2^{23}A_2^7$	40.01	28 516 091.999	951.194 442 62
R(70) A_1^2	81.54	28 516 133.529	951.195 827 92
R(86) A_1^6 $F_1^{19}E^{13}$	83.5	28 516 135.489	951.195 893 29
R(69) F_2^{12}	162.2	28 516 214.189	951.198 518 44

[1] Ch. J. Bordé, *Rev. Cethedec-Ondes et Signal NS 83-1,* 1–118 (1983).
[2] A. Clairon, A. van Lerberghe, Ch. Salomon, M. Ouhayoun, and Ch. J. Bordé, *Opt. Comm.* **35,** 368–372 (1980).
[3] A. Clairon, A. van Lerberghe, Ch. Bréant, Ch. Salomon, G. Camy, and Ch. J. Bordé, *J. Phys. Colloq.* (Paris), **42,** Suppl. to No. 12, **C8,** 127–135 (1981).