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Studies on the Rate Constants of Free Radical Reactions and Related Spectroscopic and Thermochemical Parameters

フリーラジカルの反応速度と分光学的及び熱力学的パラメーターに関する研究

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Preface

Atoms and free radicals are very important species in atmospheric chemistry, and particularly in photochemistry. Therefore, their reaction rates, and their thermodynamic and spectroscopic properties are very useful for the air pollution simulation modelling which involves the conversion of pollutants and for the spectroscopic analysis of chemical species such as laser induced fluorescence spectrometry, in addition to the study of photochemistry, reaction kinetics, and spectroscopy.

This report, consisting of three sections, is a recent review of the above physico-chemical properties of atoms and free radicals. The first section summarizes the spectroscopic constants of 30 organic free radicals and 44 inorganic free radicals such as fundamental vibrations at ground state, allowable excitation energies and vibration constants, presence or absence of laser fluorescence, and radiative life time of fluorescence. The second section contains heat of formation of 85 atoms and free radicals and the third section describes the parameters of free radical reactions such as the reaction rates at ordinary temperature, activation energies, reaction mechanisms, and techniques for measurement of reaction rate.

Thus this report will provide useful and reliable data for the study of atmospheric chemistry, photochemistry and gas phase chemical reactions.

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Abstract

This article is composed of the data of the rate constants, thermochemical parameters, and spectroscopic parameters of more than 80 kinds of atomic or radical species. The newest and the most reliable values are chosen. These data should be useful for the studies of photochemistry, reaction kinetics, and spectroscopy as well as for atmospheric chemistry and in particular for simulation studies of atmospheric reactions.

The article is divided into 3 sections. The first section deals with the spectroscopic parameters of free radicals (30 organic radicals and 44 inorganic radicals). The newest data of normal vibrations of the ground state, energy and vibrational constants of allowed excited states, presence or absence of laser induced fluorescence (LIF), and the radiative lifetime for each radical are listed. The tables are constructed with care in order to make them useful when the detection or the reaction(s) of free radicals is investigated by means of LIF. About 170 refernces are cited.

In the second section the heat of formation of 85 kinds of atoms and free radicals is tabulated. These are the newest values and of particular importance in the studies of free-radical reactions.

Rate constants for free-radical reactions are collected and arranged in the third section. Rate constants at ambient temperature, activation energies, reaction mechanisms, and methods for reaction-rate measurements are described for about 1500

reactions of more than 70 kinds of free radicals. These data are indispensable for the modelling studies of the chemical reactions taking place in the atmosphere. About 350 references are cited.

Introduction

This article consists of following three sets of Tables. They provide information useful for the analysis of free radical reactions.

1. Spectroscopic Constants for radicals
   - 1-1 Organic radicals
   - 1-2 Inorganic radicals
2. Heats of formation for radicals
3. Rate constants for the reactions of radicals
   - 3-1 group I (Atomic species)
   - 3-2 group II (Hydrocarbon radicals)
   - 3-3 group III (O-containing organic radicals)
   - 3-4 group IV (Halogen containing organic radicals)
   - 3-5 group V (N-containing inorganic radicals)
   - 3-6 group VI (O- and S-containing inorganic radicals)
   - 3-7 group VII (Other radicals)

1. The first set of Tables lists the spectroscopic parameters of known electronic states of various radicals. The energy level, vibrational frequencies of known modes, rotational constants, observed electronic transitions, and radiative lifetime are compiled for each known electronic state. The parameters for diatomic species are listed more comprehensively in "Molecular Spectra and Molecular Structure IV. Constants of Diatomic

Molecules", written by Huber and Herzberg (Ref. 4 of Table 1-1). The spectroscopic parameters for radical species consisting of more than three atoms have been determined less completely, though the recent development of laser technique facilitates the spectroscopic study of these radicals.

2. The heats of formation of radicals are very important in considering the feasibility of a particular reaction and also estimating the reaction mechanism and final products. For this reason, the heats of formation are given in the present section.

3. Although vast amount of rate data have been accumulated for radical reactions, this section has not enough space for listing all available data to make any recommendations. Therefore, for the radicals whose rate constants have not yet been established, the rate constants recently determined by various research groups are tabulated without recommendations. For the radicals whose rate constants are established, the rate constants for several typical reactants are cited from recent reviews. In both cases, readers can find more precise information by referring the original literature or reviews given in the reference column.

Each Table is followed by the list of the references.

1. Spectroscopic constants for radicals

The spectroscopic parameters for atomic species are omitted from the following Tables. The symbols and notations are those adopted by Herzberg in the series of publication, "Molecular spectra and molecular structure".[1-4] The energy levels are given as T_0 which means the energy difference between the lowest vibrational levels of excited and ground electronic states.

For diatomic radicals, both vibrational frequency and unharmonic constants are tabulated. The latter quantity is given in parentheses. For triatomic radicals, three vibrational frequencies corresponding to symmetric stretching (ν_1), bending (ν_2) and anti-symmetric stretching (ν_3) modes are listed. The modes of vibrational frequencies for radicals consisting of more than four atoms are specified whenever possible. The rotational constants given in the 5th column are those of zero vibrational level, i.e., B_0. When available, three rotational constants (A_0, B_0, and C_0) are listed for polyatomic radicals. T_0, ν_i, and B_0 are all given in the unit of cm^{-1}.

The observed transitions between listed electronic states are noted in the 6th column. The direction of the arrow expresses whether the observed transition is emission or absorption. Since laser induced fluorescence (LIF) is of great value in detecting radicals, the transitions used so far for LIF are noted as (L). The transition energies are given in unit of wavelength (nm).

In the 7th column, radiative lifetimes for various excited electronic states are given in unit of ns. The values reported from different sources are sometimes very different from each other. In such a case all values are cited. The reference to the original literature is recommended. The references are given in the 8th column or immediately after the relevant parameter (following slash mark).

Table 1-1 Spectroscopic parameters for organic radicals

radical	state	T_0 (cm^{-1})	ν_1 (cm^{-1})	ν_2 (cm^{-1})	ν_3 (cm^{-1})	B_0 (cm^{-1})	transition	(nm)	τ_r (ns)	reference
C_2	$D\,^1\Sigma_u$	43226.72	1829.57(13.94)			1.8234	D<->X	231.3	14.6	4
	$d\,^3\Pi_g$	19988.48	1788.22(16.440)			1.7447	d<->a(L)	516.0	170/4,120/76	
	$A\,^1\Pi_u$	8268.16	1608.35(12.078)			1.6079	A<->X(L)	1209.5	11μs/77,78	4
	$a\,^3\Pi_u$	609.98	1641.35(11.67)			1.6242				4
	$X\,^1\Sigma_g^+$	0	1854.71(13.340)			1.8110				4
C_3	$\tilde{B}\,^1\Sigma_u^+$?	52910	1080	300	780		$\tilde{B}$<-$\tilde{X}$	189.0		5
	$\tilde{A}\,^1\Pi_u$	24675.5	1085.9	307.9	840/6	0.4124	$\tilde{A}$<->$\tilde{X}$(L)	405.3	200/7,188/8	9
	$^3\Pi_u$	(16450)	(1209)	(415)	(1344)					10
	$\tilde{X}\,^1\Sigma_g^+$	0	1224.5/11	63.1	2040/6	0.4305				9
CH	$C\,^2\Sigma^+$	31778.1	2840.2(125.96)			14.244	C<->X(L)	314.7	(90)/12	
	$B\,^2\Sigma^-$	(25698)	(1794.9)			(12.645)	B->X	389.1	400/13	
	$A\,^2\Delta$	23217.5	2930.7(96.65)			14.585	A<->X(L)	430.7	537/14 460/15	
	$a\,^4\Sigma^-$	(6003)	(3145)			(15.4)				16
	$X\,^2\Pi_r$	0	2858.5(63.02)			14.190				
CH_2	$\tilde{B}\,^3\Sigma_u^-$	70634				3.595				17
	$\tilde{c}\,^1A_1$	30694								18
	$\tilde{b}\,^1B_1$	10084	3000	557		7.57	$\tilde{b}$<->$\tilde{a}$(L)	1410.4	4600/19 1900/20	
	$\tilde{a}\,^1A_1$	2994±30/21	(2806)/22	1353		20.14,11.16,7.06				

	$\tilde{X}^3B_1(^3\Sigma_g^-)$	0				3.950				
C_2H	$\tilde{B}^2\Sigma^+$	51390		630	2150		$\tilde{B}<-\tilde{X}$	194.6		23,24
	$\tilde{A}^2\Pi$	3800					$\tilde{A}<-\tilde{X}$			28
	$\tilde{X}^2\Sigma^+$	0	3612/26	375/25	1848/27	1.45682/28				
C_2H_3										29(calcn.)
CH_3	$\tilde{B}^2A_1'$	46205		(1360)			$\tilde{B}<-\tilde{X}$	216.4		3
	$\tilde{X}^2A_2''$	0		606.4/30	3160.8/31	,9.578,4.743/30				32
$C_6H_5CH_2$	$\tilde{A}^2A_2$	22001.5	434.2(6a)				$\tilde{A}<->\tilde{X}$(L)	454.5	880/79	33,34,80
	$\tilde{X}^2B_2$	0	523.2(6a)	614.5(6b)		(0.1831,0.0909,0.0608)				33
HCO	$\tilde{B}^2A'$	38691		1035/35	1375/35		$\tilde{B}->\tilde{X}$	258.5		36
	$\tilde{A}^2A''(^2\Pi)$	9294.0	3316.2	802.3	1813.4	1.337	$\tilde{A}<->\tilde{X}$(L)	1076	46±4/37	
	$\tilde{X}^2A'$	0	2768	1083	1820	22.369,1.4944,1.4008				
CH_3CO							abs.	215		38
CH_3O	$\tilde{A}^2A_1$	31530	680(ν_3:CO str)				$\tilde{A}<->\tilde{X}$(L)	317.1	2200/81	39,40,81
	$\tilde{X}^2E$	0	1015(ν_3)							
CH_3S	$\tilde{A}^2A_1$	26531		1316	403		$\tilde{A}<->\tilde{X}$(L)	376.8	310	82
	$\tilde{X}^2E$	0			740					
C_2H_5O	$\tilde{A}$	29200	596(CO str)				$\tilde{A}<->\tilde{X}$(L)	342.4	1800/81	41,81
	$\tilde{X}$	0	1067(CO str)							
C_2H_3O	$\tilde{A}^2A''$	28784.09	917(CO str)	1122(CC str)	450(CCO bent)	2.103,,	$\tilde{A}<->\tilde{X}$(L)	347.4	840/41	43,42

CHF	$\tilde{A}^1A''$	17287		1021		25.691,1.1616,1.107	$\tilde{A}$<->$\tilde{X}$(L)	578.5	2450/55	56,57,58
	$\tilde{X}^1A'$	0		1403		15.563,1.2230,1.1297				57
CHCl	$\tilde{A}^1A''$	(12288)		870		0.609	$\tilde{A}$<->$\tilde{X}$(L)	813.8		3
	$\tilde{X}^1A'$	0		1201	815/59	15.759,0.6048,0.5814/60				
CF_2	$\tilde{A}^1A_1$	37705	1017	494/61		5.07,0.331,0.311	$\tilde{A}$<->$\tilde{X}$(L)	265.2	55/62,61/61	
	$\tilde{a}^3B_1$	19824		508			$\tilde{a}$->$\tilde{X}$	504	lms?	63
	$\tilde{X}^1A_1$	0	1223	668	1102	2.95,0.417,0.365				64,65
CFCl	$\tilde{A}^1A''$	25283.5/66	1265/67	394/66	739	(3.4)	$\tilde{A}$<->$\tilde{X}$(L)	396	700/66,644/68	
	$\tilde{X}^1A'$	0	1158	448	750	(1.6)				66
CFBr	$\tilde{A}^1A''$	23300					$\tilde{A}$<->$\tilde{X}$(L)	429	1150/69	70
	$\tilde{X}^1A'$	0		327						70
CCl_2	$\tilde{A}^1B_1$	17093	639	305.4/83			$\tilde{A}$<->$\tilde{X}$(L)	585	3810/68	71
	$\tilde{X}^1A_1$	0	726	333	745					71
CBr_2	$\tilde{A}$	14962		186			$\tilde{A}$<->$\tilde{X}$	668	14500	72
	$\tilde{X}$	0	595	196						72
CClBr	$\tilde{A}$	16044		246			$\tilde{A}$<->$\tilde{X}$	623	5600	72
	$\tilde{X}$	0	744	260						72
CF_3	$^2A'$	51263	804				$^2A'$->$\tilde{X}(A_2'')$	180-300	12-17/84	73
	$\tilde{X}^2A$	0	1087	703	1260.16	0.36362,0.18856				74,75

	$^2A'$	8000					abs.	1250		44
	$\tilde{X}^2A''$	0	1540	1143	496	2.228,0.3809,0.3253				45(calcn.)
HCCO	$\tilde{A}$	28290	1183(CO or CC str)	866(HCC bent)			$\tilde{A}$<->$\tilde{X}$(L)	353.5	149	46
	$\tilde{X}$	0	1764(CO or CC str)	2334(CH str)						
CH_3O_2	$\tilde{B}$						abs	235-240		47
	$\tilde{A}^2A'$	7375	896(OO str)				$\tilde{A}$<-$\tilde{X}$			48
	$\tilde{X}^2A''$	0								49
$C_2H_5O_2$	$\tilde{A}$	7593	918(OO str)				$\tilde{A}$<-$\tilde{X}$			48
	$\tilde{X}$	0								
C_2O	$\tilde{A}^3\Pi$	11620	2045.7	607.8	1270		$\tilde{A}$<->$\tilde{X}$(L)	860.6	333,14.5/50	51
	$^1\Pi$	(7670)								52(calcn.)
	$\tilde{X}^3\Sigma^-$	0	1978	379.4	1074					51
CF	$B^2\Delta_r$	49340.1	1153.34(19.4)			1.3092	B<->X	202.7	18.8	
	$A^2\Sigma^+$	42924.17	1780.45(30.73)			1.7193	A<->X	233.0	19	
	$a^4\Sigma^-$	28564	(1324)			1.3035	a->X			53
	$X^2\Pi_r$	0	1286.1(11.10)			1.4075/54				
CCl	$A^2\Delta$	36004	(848.1)			(0.7062)	A<->X	278		4
	$X^2\Pi_{1/2}$	0	(866.7)			0.6903				
CBr	$A^2\Delta$	32753				(0.495)	A<->X	305		4
	$X^2\Pi_{1/2}$	0				(0.4877)				

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Table 1-2 Spectroscopic parameters for inorganic radicals

radical	state	T_0 (cm^{-1})	ν_1 (cm^{-1})	ν_2 (cm^{-1})	ν_3 (cm^{-1})	B_0 (cm^{-1})	transition	(nm)	τ_r (ns)	reference
NH	$c^1\Pi$	43345	2122.64			14.240	c<->a(L)	325.1	411	4
	$A^3\Pi_i$	29776.76	3231.2(98.6)			16.302	A<->X(L)	335.8	440/57	4
	$b^1\Sigma^+$	21238	3352.4(74.24)			16.409	b->X	478	53±15ms/5, 17.8ms/6	
	$a^1\Delta$	12589	3188(68)			16.109	a->X	795	>33s/58	4
	$X^3\Sigma^-$	0	3282.27(78.35)			16.3748				4
NH_2	$\tilde{A}^2A_1(\Pi)$	10249	3325	633		8.78	$\tilde{A}$<->$\tilde{X}$(L)	430-900	10μs/7, 10.3μs/8	3
	$\tilde{X}^2B_1$	0		1497.2		23.72, 12.94, 8.16				3
N_3	$\tilde{B}^2\Sigma_u^+$	36739.1				0.43238	$\tilde{B}$<-$\tilde{X}$	260-273		3
	$\tilde{X}^2\Pi_g$	0				0.43117				3
HNO	$\tilde{A}^1A''$	13154.4	2854.2	1420.8	981.2	22.164, 1.3255, 1.243	$\tilde{A}$<->$\tilde{X}$(L)	770-550	22-29μs/9	3
	$\tilde{X}^1A'$	0	3596	1562	1110	18.479, 1.4115, 1.307				3
NO_3	$\tilde{A}^2E'$?	15108	931(ν_1), 820(ν_2), 1166(ν_5), 418(ν_6)/11				$\tilde{A}$<->$\tilde{X}$(L)	662	2.8μs/10, 23μs/11	
	$\tilde{X}^2A_2'$	0	1060(ν_1), 754(ν_2), 1492(ν_3), 380(ν_4)			0.45746, 0.2287				12
CN	$B^2\Sigma^+$	25797.84	2163.9(20.2)			1.962	B<->X(L)	387.6	70.5/13	4
	$A^2\Pi_i$	9117.38	1812.56(12.609)			1.7066	A<->X	1097	8.5μs/59	4
	$X^2\Sigma^+$	0	2068.59(13.087)			1.89106				4
NCO	$\tilde{B}^2\Pi$	31753.1	2303		1047	0.3765	$\tilde{B}$<-$\tilde{X}$	320-265		3
	$\tilde{A}^2\Sigma^+$	22754.0	2338.0	680.8	1289.3	0.4021	$\tilde{A}$<->$\tilde{X}$(L)	450-350	350/14, 435/15	

	$\tilde{X}^2\Pi_i$	0	1923/16	535.4/17	1272/15	0.3894				3
NCS	$\tilde{B}^2\Sigma^+$	26844		343		0.1969	$\tilde{B}\leftarrow\tilde{X}$	370		64
	$\tilde{A}^2\Pi_i$	26054	1916	378	755	0.1906	$\tilde{A}\leftrightarrow\tilde{X}$(L)	385-345	164±10/65	64
	$\tilde{X}^2\Pi_i$	0		387	715	0.2036				64
CCN	$\tilde{C}^2\Sigma^+$	26661.73	1859.2	(465)		0.4129	$\tilde{C}\leftarrow\tilde{X}$	375-348		3
	$\tilde{B}(^2\Sigma^-)$	22413.25				0.4151	$\tilde{B}\leftarrow\tilde{X}$	447-445		3
	$\tilde{A}^2\Delta_i$	21259.15	1770.77	475	1241.64	0.4137	$\tilde{A}\leftrightarrow\tilde{X}$(L)	471-377	170/19	3,18
	$\tilde{X}^2\Pi_r$	0	1917	(210)	1060	0.3981				20,21
CNC	$\tilde{B}^2\Sigma_u^-$	34802.3		398		0.4430	$\tilde{B}\leftarrow\tilde{X}$	288-283		3
	$\tilde{A}^2\Delta_u$	30338.5		440		0.4504	$\tilde{A}\leftarrow\tilde{X}$	332-325		3
	$\tilde{X}^2\Pi_g$	0		321	1453/22	0.4535				3
NCN	$\tilde{B}^3\Sigma_u^-$	33215			(1045)		$\tilde{B}\leftarrow\tilde{X}$	330-240		23
	$\tilde{A}^3\Pi_u$	30838.7		(510)		0.3962	$\tilde{A}\leftrightarrow\tilde{X}$(L)	330-326		3,24
	$\tilde{X}^3\Sigma_g^-$	0		(423)	(1475)/23	0.3968				3
CNN	$\tilde{B}^3\Sigma_u^-$	(39950)	(990)	(460)	(1450)		$\tilde{B}\leftarrow\tilde{X}$	250-210		25
	$\tilde{A}^3\Pi_u$	(23591)			(1322)		$\tilde{A}\leftrightarrow\tilde{B}$	424	280	24
	$\tilde{X}^3\Sigma_g^-$	0	(1241)	(393)	(2847)					26,27
NF	$b\,^1\Sigma^+$	18905.25	1197.49(8.64)			1.23042	b->X	529	22.6ms/60	4
	$a\,^1\Delta$	11435.2	1184(8.5)			(1.2225)	a->X	874	5.6s	61
	$X\,^3\Sigma^-$	0	1141.37(8.99)			1.1982				4,28

NCl	$b^1\Sigma^+$	15040.09/29	935.6(5.4)			0.682567	b->X	665	250±50/62	4,29
	$a^1\Delta$	9280	904(4.7)				a->X	1076	20±0.2/63	30
	$X^3\Sigma^-$	0	827.0(5.1)			0.64657				4,29
NBr	$b^1\Sigma^+$	14834.3	785.5(4.363)			0.4657	b->X	674		4
	$a^1\Delta$	9226	763(2.4)				a->X	1080		30
	$X^3\Sigma^-$	0	691.75(4.720)			0.442				4
HNF	$\tilde{A}^2A'$	20141.26				27.570,1.033,0.992	$\tilde{a}$<->$\tilde{X}$	538-510		31
	$\tilde{X}^2A''$	0		1441.1		17.688,1.039,0.978				32
NF_2	$\tilde{A}$	(36000)		(380)			$\tilde{A}$<-$\tilde{X}$	280-235		3
	$\tilde{X}(^2B_1)$	0	1074.990	(573.4)	(930.7)	2.3515,0.3960,0.3381				3,33,34
NCl_2	$\tilde{A}$?	(33900)?		(550)			$\tilde{A}$<-$\tilde{X}$	240 diffuse		35
	$\tilde{X}$	0								
OH	$A^2\Sigma^+$	32402.4	3178.86(92.917)			16.965	A<->X(L)	308.6	690(N=1)/36	4
	$X^2\Pi_i$	0	3737.761(84.8813)			18.5487				4
HO_2	$\tilde{A}^2A'$	7029.48	3268.5	1285	984.8	20.464,1.022,0.969	$\tilde{A}$<->$\tilde{X}$	1423		37,38
	$\tilde{X}^2A''$	0	3436/39	1390	1097.6	20.357,1.118,1.056				40
SH	$A^2\Sigma^+$	30662.42	1979.8(97.6)			8.289	A<->X(L)	322.2	3.2(dissn.)/66	
	$X^2\Pi_i$	0	2711.6(59.9)			9.326				4
SF	$A^2\Pi$	(24995)	488(3.1)-3/2, 483(2.6)-1/2			0.552	A<-X	400-345		41
	$X^2\Pi$	0	837.64/42			0.55265				4

CS	$A'^1\Sigma^+$	56093	462.4(7.46)			0.5060	A'->X	178	15/43	
	$A^1\Pi$	38797.6	1073.4(10.1)			0.7769	A<->X(L)	257.7	176,200	4
	$a^3\Pi_r$	27585.7	1135.1(7.73)			0.7815	a->X	362.5		4
	$X^1\Sigma^+$	0	1285.08(6.46)			0.820046				4
NS	$C^2\Sigma^+$	43387.4	1389			0.8275	C<->X	230	6.5	4
	$A^2\Delta_r$	39875.7	943.9(8.4)			0.6850	A<->X	251		4
	$B^2\Pi_r$	30085.0	797.31(3.72)			0.5962	B<->X(L)	332	1.0-1.3μs/67	4
	$b^4\Sigma$	29169	935(7.2)			0.674				68
	$X^2\Pi_r$	0	1218.7(7.28)			0.7660				4
SO	$B^3\Sigma^-$	41370	630.4(4.79)			0.4989	B<->X	241.7	17.3	4
	$A^3\Pi$	37940(0)	415.2(1.6)			0.5970	A<->X(L)	263.6	12.4μs/4,35.9μs/70	
	$b^1\Sigma^+$	10469.3	1068.66(7.25)			0.6995	b->X	955		4
	$a^1\Delta$	5865/69	1115.39(6.978)/44			0.71034				4
	$X^3\Sigma^-$	0	1150.71(6.35)/45			0.7181				4
S_2	$B^3\Sigma_u^-$	31667	434.0(2.75)			0.2204	B<->X(L)	315.6	30-45/71,17/4	4
	$b^1\Sigma^+$	7961/69	699.7(3.4)							4
	$a^1\Delta_g$	(22000)	702.35(3.09)			0.2918				4
	$X^3\Sigma_g^-$	0	725.65(2.844)			0.2947				4
HS_2	$\tilde{A}^2A'$	7255			504		$\tilde{A}$->$\tilde{X}$	1378		72
	$\tilde{X}^2A''$	0		904	595					72

S_2O	$\tilde{B}$?			270	378		$\tilde{B}$<-$\tilde{X}$	190-230		73
	$\tilde{A}\,^1A'$	29696	1030	405	252	1.017,0.149,0.129	$\tilde{A}$<->$\tilde{X}$(L)	250-340	10/75	74,75
	$\tilde{a}$	<14200	1076	449	302					76
	$\tilde{X}\,^1A'$	0	1165	679	388	1.3981,0.1688,0.1503				74,77
HSO	$\tilde{A}\,^2A'$	14514		672(SO str)			$\tilde{A}$<->$\tilde{X}$(L)	689	11.3/47	46
	$\tilde{X}\,^2A''$	0		1026(SO str)		9.982,0.683,0.638/44				48
FO	$X^2\Pi$	0	1028.7(5.15)			1.099				4
ClO	$A^2\Pi_i$	31482.3	519.5(7.2)			0.4420	A<->X	317.6		4
	$X^2\Pi_i$	0	853.8(5.5)			0.6205				4
BrO	$A^2\Pi_{3/2}$	27725	485.9(5.40)				A<-X	360.7		4
	$X^2\Pi_{3/2}$	0	778.7(6.82)			0.42778				4
IO	$A^2\Pi_{3/2}$		514.57(5.52)			0.2750	A<->X(L)	465.7	<10/49	4
	$X^2\Pi_{3/2}$	0	681.47(4.29)			0.3389				4
ClO_2	$\tilde{A}\,^2A_2$	21016.4	707.1	289.6	769.3		$\tilde{A}$<-$\tilde{X}$	475.8		3,50
	$\tilde{X}\,^2B_1$	0	945.5	447.4	1110.5	1.7372,0.332,0.278				3
SiH	$A^2\Delta$	24193.04	1858.90(99.175)			7.2942	A<->X(L)	413.3	700/4,534/78	4
	$X^2\Pi_r$	0	2041.80(35.51)			7.3901				4
SiF	$B^2\Sigma^+$	34638.5	1011.23(4.825)			0.62707	B->X	288.7		4
	$a^4\Sigma^-$	29807.9	863.16(5.370)			0.57862	a->X	335.5		4
	$A^2\Sigma^+$	22787.6	718.58(10.167)			0.57839	A<->X	438.8	230	4

	$X^2\Pi_r$	0	857.19(4.735)			0.58121				4
SiCl	$B^2\Sigma^+$	34193.6	706.6(3.9)			0.2775	B<->X	292.5		4
	$A^2\Sigma$	22994.7	294.95(0.73)			0.1983	A<-X	434.9		4
	$X^2\Pi_r$	0	535.60(2.168)			0.2553				4
SiH_2	$\tilde{A}^1B_1$	15533		860		17.75,4.9,(3.8)	$\tilde{A}$<->$\tilde{X}$(L)	480-650	60±5/52	51
	$\tilde{a}^3B_1$	<4900								53
	$\tilde{X}^1A_1$	0		1004		8.0964,7.021,3.700				51
SiHF	$\tilde{A}^1A''$	23260		560			$\tilde{A}$<->$\tilde{X}$(L)	430-390	185±10	83
	$\tilde{X}^1A'$	0	1913	860	834					84
SiHCl	$\tilde{A}^1A''$	20717.7	(1250)	563.7	532.6	9.857,0.2464,0.2404	$\tilde{A}$<->$\tilde{X}$(L)	610-410		3,85
	$\tilde{X}^1A'$	0		805.5	522.4	7.587,0.2461,0.2383				3
SiHBr	$\tilde{A}^1A''$	19903.1	(1270)	535.1	412.2	9.906,0.1589,0.1563	$\tilde{A}$<->$\tilde{X}$			3
	$\tilde{X}^1A'$	0	1547.8	771.4	408.0	7.580,0.1578,0.1546				3
SiF_2	$\tilde{A}^1B_1$	44109	790	252			$\tilde{A}$<->$\tilde{X}$	213-233		54
	$\tilde{a}^3B_1$	26310		277			$\tilde{a}$<-$\tilde{X}$	380		55
	$\tilde{X}^1A_1$	0	855.01	345	870.41	1.0208,0.2943,0.2278				56
$SiCl_2$	$\tilde{A}^1B_1$	30760/81		147/81			$\tilde{A}$<->$\tilde{X}$(L)	315-335	66/81	79,80
	$\tilde{X}^1A_1$	0	502/82	199/81	513/82					
SiF_3	$\tilde{X}^2A$	0	832,954(SiF str),406(umbrella),290(deformn)							86

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2. Heats of formation for radicals

The heats of formation at 0 K and 298 K are tabulated for various radicals in the unit of kJ/mol. The possible uncertainty in the evaluated heat of formation is also given when it is reported. The main sources of this list are as follows:

(1) Stull, D.R. and H. Prophet (1972) : JANAF Thermochemical Tables 2nd ed., U.S. Department of Commerce, and its Supplements published in 1974, 1975, 1978, and 1982.

(2) Baulch, D.L., R.A. Cox, R.F. Hampson, Jr., J.A. Kerr, J. Troe, and R.T. Watson (1980) : Evaluated kinetic and photochemical data for atmospheric chemistry. J. Phys. Chem. Ref. Data, **9**, 295, and its supplements [J. Phys. Chem. Ref. Data, **11**, 327 (1982); (1984) : ibid., **13**, 1259].

(3) Benson, S.W. (1979) : Thermochemical Kinetics, Wiley Interscience, New York.

The above three sources are indicated by the abbreviations such as J82 (1982 supplement of (1)), DATA (source (2)) and B (source (3)). When the heat of formation is cited from other recent paper, the source is indicated in the reference list.

Table 2 Heat of formation of radicals

radical	$\Delta H_f^0(298)$ (kJ/mol)	$\Delta H_f^0(0)$ (kJ/mol)	Ref.
H	217.997	216.03	DATA
$C(^3P)$	716.68	711.20	J82
(^1D)		833.12	
(^1S)		970.13	
$N(^4S)$	472.68	470.82	DATA
(^2D)		700.79	
(^2P)		815.83	
$O(^3P)$	249.17	246.78	DATA
(^1D)		436.61	
(^1S)		651.03	
$Si(^3P)$	450.6	446.3±4	J71
(^1D)		521.6	
(^1S)		630.4	
$S(^3P)$	276.98	274.72	J82
(^1D)		385.24	
(^1S)		540.06	
F	79.39	77.28	DATA
$Cl(^2P_{3/2})$	121.30	119.62	DATA
$(^2P_{1/2})$		130.16	
$Br(^2P_{3/2})$	111.86	117.90	DATA
$(^2P_{1/2})$		161.98	

I ($^2P_{3/2}$)	106.762	107.25	DATA
($^2P_{1/2}$)		198.20	
C_2	838±4	829±4	J71
C_3	820±20	812±20	J71
C_2H	536		DATA
CH	594.1	590.8	DATA
CH_2	386	386	DATA
C_2H_3	285		DATA
C_3H_5	164.9		DATA
CH_3	145.6	149.0	DATA
C_2H_5	107.5		DATA
n-C_3H_7	94.6±7.5		DATA
i-C_3H_7	76.2±6.3		DATA
i-C_4H_9	57.3		B
t-C_4H_9	35.1		B
C_6H_5	328		B
$C_6H_5CH_2$	188		B
C_2O	380±15		B
HCO	37.6	37.2	DATA
CH_3CO	-24.3		DATA
C_6H_5CO	111		B
CH_2OH	-25.9		DATA
CH_3O	14.6	22.6	DATA
C_2H_5O	-17.2		DATA

CH_3O_2	16±8		DATA
$C_2H_5O_2$	-7.5		DATA
CCl	502±20	498±20	DATA
CBr	510±60	515±60	J71
CHF	125±30		J71
CFCl	30±25	30±25	DATA
CCl_2	238±20	237±20	DATA
CF_2	-182±8	-182±8	DATA
CF_3	-470±4	-468±4	DATA
CF_2Cl	-269		DATA
$CFCl_2$	-96		DATA
CCl_3	79.5	80.1	DATA
CH_2Br	163		DATA
FCO	-170±60	-170±60	DATA
NH	379.5±2	379.5±2	1
NH_2	185	188	DATA
N_3	414±20	417±20	J74
HNO	99.6	102.5	DATA
NO_3	71±20	77±20	DATA
CN	435.1±10	431.8±10	J71
NCO	159.4±10		J74

CCN	556±125		J71
CNN	585±125		J71
NCN	473±40		J74
NF	249±33		J71
NCl	260±10		2
NF_2	42.3±8	44.8±8	J71
OH	39.0	38.7	DATA
HO_2	10.5±4.2		DATA
SH	146±4	145±4	DATA
SF	13.0±6	12.1±6	J78
CS	272	268	DATA
SO	5.0	5.0	DATA
SOH	21±17		DATA
S_2	128.49	128.20	DATA
$HOSO_2$	-481±25		DATA
OF	109±8	109±8	DATA
OCl	102	102	DATA
OBr	125	133	DATA
OI	172		DATA
FO_2	50±12	52±12	DATA
ClO_2	89±5	91	DATA
OClO	97±8	100±8	DATA
SiH	337±8	375±8	J82

SiH_2	248±6	250±6	3,4,5
SiHF	-173±20	-172±20	3
SiF_2	-588±1	-587±1	3
$SiCl_2$	-169±3	-169±3	J82
SiH_3	195±6	200±6	3
SiF_3	-1000±5	-997±5	3
SiH_4	34.3±2	43.9±2	J78

References for Table 2

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2. Clark, Y.C. and M.A.A. Clyne (1970) : Trans. Faraday Soc., **66**, 877.
3. Schlegel, H.B. (1984) : J. Phys. Chem., **88**, 6254.
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3. Rate constants for radical reactions

As mentioned above, this section consists of seven separate Tables. The radicals are devided into seven groups as a matter of convenience. The radicals treated in each Table are given below.

Table 3-1 Group I (Atomic species)

H, C(*), N(*), O(*), Si(*), S(*), F, Cl(*), Br(*), I(*)

Table 3-2 Group II (Hydrocarbon radicals)

C_2(*), C_3(*), CH(*), CH_2(*), C_2H, C_2H_3, C_3H_5,
CH_3, C_2H_5, C_3H_7, C_4H_9, C_5H_9, $C_6H_5CH_2$

Table 3-3 Group III (Oxygen-containing organic radicals)

C_2O(*), HCCO, HCO, CH_3CO, C_6H_5CO, CH_2OH, CH_3O,
C_2H_5O, C_2H_3O, CH_3O_2, $C_2H_5O_2$, $C_3H_7O_2$

Table 3-4 Group IV (Halogen-containing organic radicals)

CCl, CBr, CHF, CF_2(*) , CFCl, CFBr, CCl_2, CF_3, CF_2Cl,
CCl_3, $CFCl_2O_2$, CCl_3O_2

Table 3-5 Group V (Nitrogen-containing radicals)

NH(*), NH_2(*), N_3, HNO, NO_3, CN, NCO, NF(*), NF_2,
NCl(*), NCl_2

Table 3-6 Group VI (Oxygen- and sulfur-containing radicals)

OH, HO_2, SH, SF, CS, SO(*), $HOSO_2$

Table 3-7 Group VII (Other radicals)

FO, ClO, ClO_2, BrO, IO, SiH, SiH_3, $SiCl_2$

The asterisk in parentheses means that the rate constants for electronically excited state(s) are listed in addition to those for the ground state. The rate constants of electronically excited species are usually determined from the decay rate of the excited species. Therefore, "reaction" includes both chemical reaction and physical quenching. When the final products of the reaction are specified, it is stated in the Comment column.

Reactants for the radical reactions are given in the 1st column in the order of increasing complexity (rare gases, atoms, radicals, inorganic molecules, and organic molecules). The second column shows the rate constants of the reaction in unit of $cm^3 molecule^{-1} s^{-1}$ at the temperature given in the 3rd column. The third order rate constant such as termolecular recombination in low pressure limit is expressed as the second order rate constant by multiplying the concentration (molecule cm^{-3}) of the specified third body, e.g., 6.3×10^{-33}[He]. When the Arrhenius parameters are available, both the A-factor and the activation energy are given together with the standard deviations. The unit of the A-factor is $cm^3 molecule^{-1} s^{-1}$, and that of the activation energy is expressed as temperature (Kelvin). One can calculate the value of the activation energy in unit of kcal mol^{-1} or kJ mol^{-1} by multiplying 1.987×10^{-3} or 8.314×10^{-3}, respectively. The given Arrhenius expressions are applicable over the temperature range given in the 3rd column.

The comments for each reaction are given in the 4th column. When the products of the reaction are identified, they are written first. Then, the experimental techniques used for the evaluation of rate constants are noted in the abbreviated form as shown below.

Methods of reactant formation:

- P stationary photolysis
- FP flash photolysis
- LP laser photolysis
  - (MPD) multi-photon dissociation by UV laser
  - (IRMPD) multi-photon dissociation by IR laser
- PR pulse radiolysis
- PY pyrolysis
- ST pyrolysis by shock wave
- DF Discharge flow
- MM molecular modulation

Methods of product or reactant detection:

- A absorption of light
  - (V, UV,IR) absorption of visible, ultraviolet, or infrared light
  - (L) absorption of laser light
  - (IC) intra-cavity laser absorption
- RA resonance absorption
- RF resonance fluorescence (resonance lamp)
- LIF laser-induced fluorescence
- LMR laser magnetic resonance
- CL chemiluminescence
- FQ fluorescence quenching
- EPR electron paramagnetic resonance
- MS mass spectrometry
  - (PI) photoionization mass spectrometry

FTIR Fourier-transform IR spectrometry

GC gas chromatography

When the rate constants are cited from review articles, it is noted in the Comment column as "Review".

The last column gives the refernce No. in the reference list which follows the Table.

Table 3-1 Rate constants for atoms of group I

Reactants	Rate constant ($cm^3 molecule^{-1} s^{-1}$)	Temp. (K)	Comments	Ref.
$H(^2S)$				
H	$(8.3\pm4.0)\times10^{-33}[H_2]$	300	H_2, Review	1
$O(^3P)$	$(2.2\pm0.5)\times10^{-32}[H_2]$	1500-2500	OH, Review	2
N	$(6.9\pm1.5)\times10^{-31}T^{-0.5}[N_2]$	1500-2500	NH, Review	2
OH	$4.3\times10^{-25}T^{-2.6}[He]$	230-300	H_2O, Review	1
CH	$(2.8\pm3.0)\times10^{-29}T^{-1.0}[H_2]$	1500-2500	CH_2, Review	2
SH	$(2.5\pm5.0)\times10^{-11}$	298	H_2+S, Review	2
HO_2	$(6.7\pm6.0)\times10^{-12}$	298	H_2+O_2, Review	3
	$(6.4\pm3.0)\times10^{-11}$	298	2OH, Review	3
H_2	$7.1\times10^{-11}\exp(-3890/T)$	300-1000	H_2+H, Review	4
O_2	$(5.9\pm1.0)\times10^{-32}(T/300)^{-1.0\pm0.5}[N_2]$	200-400	HO_2, Review	3
HCl	$3.8\times10^{-11}\exp(-1760/T)$	195-497	H_2+Cl, Review	4
NO	$(2.1\pm1.2)\times10^{-32}\exp(+300/T)[H_2]$	220-400	HNO, Review	1
F_2	$2.0\times10^{-10}\exp(-1210/T)$	294-565	HF+F, Review	4
Cl_2	$(1.46\pm0.4)\times10^{-10}\exp(-593/T)$	250-700	HCl+Cl, Review	1
CO	$(2.0\pm0.6)\times10^{-33}\exp(-850/T)[H_2]$	298-773	HCO, Review	1
O_3	$(1.4\pm1.0)\times10^{-10}\exp(-480\pm100/T)$	220-360	OH+O_2, Review	3
NO_2	$(4.8\pm1.2)\times10^{-10}\exp(-400\pm70/T)$	298-653	OH+NO, Review	1
H_2S	$1.3\times10^{-11}\exp(+860/T)$	190-464	H_2+HS, Review	1
OCS	$(2.2\pm1.3)\times10^{-14}$	300	CO+HS, Review	1
NH_3	$6.8\times10^{-11}\exp(-6900/T)$	843-963	H_2+NH_2, Review	4
CH_4	$1.26\times10^{-10}\exp(-6000/T)$	400-1800	H_2+CH_3, DF	5
C_2H_6	$1.9\times10^{-10}\exp(-4600/T)$	290-579	$H_2+C_2H_5$, Review	4
C_2H_4	$(4.6\pm0.3)\times10^{-11}\exp(-1080/T)$	206-461	PR-RA	6

C_3H_6	$(1.7\pm0.1)\times10^{-12}$	298	PR-RA	7
C_2H_2	$(3.8\pm0.2)\times10^{-11}\exp(-1370/T)$	206-461	PR-RA	8
H_2CO	$2.2\times10^{-11}\exp(-1880/T)$	297-652	H_2+HCO, Review	4
H_2CCO	$(1.88\pm1.12)\times10^{-11}\exp(-1725\pm190/T)$	298-500	FP-RF	9
$(CH_3)_2S$	$(2.8\pm0.4)\times10^{-11}\exp(-2621\pm88/T)$	27-199	CH_3SH+CH_3, FP-PA	10

$C(^3P)$

H_2	$(6.9\pm1.2)\times10^{-32}$[He]	300	CH_2, FP-RA	11
	$(7.1\pm2.5)\times10^{-32}$[He]	300	CH_2, FP-RA	12
N_2	$(3.1\pm1.5)\times10^{-33}$[Ar]	300	FP- RA	12
O_2	$(2.6\pm0.3)\times10^{-11}$	300	FP-RA	11
	$(3.5\pm1.5)\times10^{-11}$	300	FP-RA	12
	3.3×10^{-11}	300	FP-A	13
	2.5×10^{-12}	300	DF-RA	14
NO	$(4.8\pm0.8)\times10^{-11}$	300	FP-RA	11
	$(7.3\pm2.2)\times10^{-11}$	300	FP-RA	12
	1.1×10^{-10}	300	FP-A	13
CO	$(6.3\pm2.7)\times10^{-32}$[He]	300	FP-RA	12
CO_2	$<10^{-15}$	300	FP-RA	11
	$<10^{-14}$	300	FP-RA	12
N_2O	$(1.3\pm0.3)\times10^{-11}$	300	FP-RA	11
	$(2.5\pm1.6)\times10^{-11}$	300	FP-RA	12
H_2O	$<10^{-12}$	300	FP-RA	11
	$\leq3.6\times10^{-13}$	300	FP-RA	12
C_3O_2	$(1.8\pm0.2)\times10^{-10}$	300	FP-RA	11
CH_4	$<2.5\times10^{-15}$	300	FP-RA	12
	$<6\times10^{-17}$	300	DF-RA	14
C_2H_4	$<6\times10^{-17}$	300	DF-RA	14
C_2H_2	$<6\times10^{-17}$	300	DF-RA	14

$C(^1D)$

He	$<3\times10^{-16}$	300	FP-RA	15
Ar	$\leq10^{-15}$	300	FP-RA	15
Xe	$(1.1\pm0.3)\times10^{-10}$	300	FP-RA	15
H_2	$(2.6\pm0.3)\times10^{-10}$	300	FP-RA	16
	4.15×10^{-11}	300	FP-A	13
N_2	$(4.1\pm1.2)\times10^{-12}$	300	FP-RA	16
	2.5×10^{-12}	300	FP-A	13
O_2	2.6×10^{-11}	300	FP-RA	17
	$<5\times10^{-12}$	300	FP-A	13
NO	$(4.7\pm1.3)\times10^{-11}$	300	FP-RA	17
	9.2×10^{-11}	300	FP-A	13
CO	$(1.6\pm0.6)\times10^{-11}$	300	FP-RA	17
CO_2	$(3.7\pm1.7)\times10^{-11}$	300	FP-RA	17
N_2O	$(1.4\pm0.5)\times10^{-10}$	300	FP-RA	17
H_2O	1.7×10^{-11}	300	FP-RA	17
CH_4	$(2.1\pm0.5)\times10^{-10}$	300	FP-RA	17
	3.2×10^{-11}	300	FP-A	13
C_2H_4	3.7×10^{-10}	300	FP-RA	17

$C(^1S)$

He	$<10^{-15}$	300	FP-RA	18
	$<2\times10^{-15}$	300	FP-RA	19
Xe	$(7\pm1)\times10^{-12}$	300	FP-RA	20
H_2	$<5\times10^{-13}$	300	FP-RA	18
	$\leq4\times10^{-14}$	300	FP-RA	19
	$<5\times10^{-12}$	300	FP-A	13
	2×10^{-14}	300	PR-A	21

N_2	$<3\times10^{-15}$	300	FP-RA	19
	$(3.2\pm0.2)\times10^{-12}$	300	FP-RA	20
O_2	$(9.9\pm1.8)\times10^{-12}$	300	FP-RA	18
	5×10^{-14}	300	FP-RA	21
Cl_2	$(7.6\pm0.7)\times10^{-11}$	300	FP-RA	20
NO	$(4.8\pm0.5)\times10^{-11}$	300	FP-RA	18
CO	$\leq6\times10^{-14}$	300	FP-RA	19
	$\leq3.5\times10^{-16}$	300	PR-A	21
CO_2	$\leq1.0\times10^{-16}$	300	PR-A	21
	3×10^{-12}	300	FP-RA	20
N_2O	$\leq5\times10^{-12}$	300	FP-RA	18
H_2O	1.6×10^{-11}	300	FP-RA	20
C_3O_2	1×10^{-10}	300	FP-RA	19
CH_4	$\leq10^{-11}$	300	FP-RA	19
	3.0×10^{-14}	300	PR-A	21
	$<10^{-12}$	300	FP-RA	20
C_2H_4	$(9.0\pm1.6)\times10^{-11}$	300	FP-RA	18
C_3H_6	$(1.0\pm0.5)\times10^{-10}$	300	FP-RA	20
C_2H_2	$(5.2\pm1.2)\times10^{-11}$	300	FP-RA	20
CCl_4	$(2.7\pm0.5)\times10^{-11}$	300	FP-RA	18
	$(3.3\pm0.4)\times10^{-11}$	300	FP-RA	20

$N(^4S)$

C	$(9.4\pm2.5)\times10^{-33}[Ar]$	298	DF-RA	22
N	$(8.3\pm5.0)\times10^{-34}\exp(+500/T)[N_2]$	100-600	N_2, Review	1
O	$(1.8\pm1.0)\times10^{-31}T^{-0.5}[N_2]$	200-400	NO, Review	1
HO	$(3.8\pm1.5)\times10^{-11}\exp(+85\pm100/T)$	250-500	NO+H, Review	3
O_2	$(4.4\pm2.0)\times10^{-12}\exp(-3220\pm350/T)$	280-330	NO+O, Review	3

$O_2(^1\Delta)$	$<1x10^{-16}$	200-300	NO+O, Review	3
NO	$(3.1\pm1.5)x10^{-11}$	200-400	N_2+O, Review	3
NO_2	$(3.0\pm1.5)x10^{-12}$	298	N_2O+O, Review	3
O_3	$<1.0x10^{-15}$	298	NO+O_2, Review	3
C_2H_4	$(6.5\pm1.3)x10^{-14}$	300	PR-RA	23
C_3H_6	$(1.1\pm0.2)x10^{-14}$	300	PR-RA	23
cis-2-Butene	$(6.5\pm0.8)x10^{-14}$	300	PR-RA	23
C_2H_2	$(1.7\pm0.2)x10^{-14}$	300	PR-RA	23
1,3-Butadiene	$(1.1\pm0.1)x10^{-13}$	300	PR-RA	23
$N(^2D)$				
O	$(2^{+2}_{-1})x10^{-12}$	300	Quenching, Review	24
He	$<1.5x10^{-16}$	300	Quenching, Review	24
Ar	$(1.0\pm0.6)x10^{-16}$	300	Quenching, Review	24
H_2	$(2.2\pm0.8)x10^{-12}$	300	NH+H?, Review	24
N_2	$(9.4^{+6.9}_{-4.2})x10^{-14}exp(-510\pm155/T)$	200-400	Quenching, Review	24
O_2	$3.5x10^{-13}T^{0.5}$	200-400	NO+O(^3P,^1D), Review	24
NO	$(6.3\pm2.0)x10^{-11}$	300	N_2+O(^3P,^1D,^1S), Review	24
CO	$(2.5\pm1.0)x10^{-12}$	300	Quenching, Review	24
N_2O	$(1.2\pm0.3)x10^{-11}exp(-570\pm70/T)$	200-400	N_2+NO, Review	24
CO_2	$(2.5^{+2.0}_{-1.0})x10^{-13}$	300	NO+CO, Review	24
H_2O	$(2.5\pm0.5)x10^{-10}$	300	NH+OH?, Review	24
NH_3	$5x10^{-11}$	300	NH+NH_2?, Review	24
CH_4	$1.5x10^{-12}$	300	Review	24
C_2H_4	$6x10^{-11}$	300	Review	24

$N(^2P)$

O	1×10^{-11}	300	Review	24
N	$1\times10^{-12\pm0.3}$	300	Review	24
Ar	7×10^{-16}	400	Review	24
H_2	$(1.5\pm1.0)\times10^{-15}$	300	Review	24
N_2	$2\times10^{-18\pm0.5}$	300	Quenching, Review	24
O_2	$(2\pm1)\times10^{-12}$	300	$NO+O(^1D,^1S)$?, Review	24
NO	$(3.0\pm0.5)\times10^{-11}$	300	Review	24
CO	$8\times10^{-14\pm1}$	300	Review	24
N_2O	$(4^{+3}_{-2})\times10^{-14}$	300	N_2+NO?, Review	24
CO_2	$(1.25\pm0.25)\times10^{-15}$	300	Quenching, Review	24

$O(^3P)$

H	$(2.2\pm0.5)\times10^{-32}[H_2]$	1500-2500	OH, Review	2
O	$(5.2\pm1.3)\times10^{-35}\exp(+900/T)[Ar]$	190-4000	O_2, Review	1
N	$2.6\times10^{-31}T^{-0.5}[N_2]$	200-400	NO, Review	2
OH	$(2.3\pm1.0)\times10^{-11}\exp(+110\pm100/T)$	220-500	O_2+H, Review	3
SH	$(1.6\pm0.5)\times10^{-10}$		SO+H, Review	1
CN	1.8×10^{-11}	295	CO+N, Review	1
ClO	$(6.4\pm2.0)\times10^{-11}\exp(-120\pm120/T)$	220-370	O_2+Cl, Review	3
NH_2	3.5×10^{-12}	300	HNO+H, HO+NH, Review	1
HO_2	$(2.9\pm1.0)\times10^{-11}\exp(+200\pm200/T)$	200-400	$HO+O_2$, Review	3
CH_3	$(1.1\pm0.8)\times10^{-10}$	200-300	$H+H_2CO$, Review	3
NO_3	$(1^{+2}_{-0.5})\times10^{-11}$	298	O_2+NO_2, Review	3
CHO	$(2.1\pm0.4)\times10^{-10}$		CO_2+H, CO+HO, Review	1
H_2	9×10^{-18}	298	$HO+O_2$, Review	3
O_2	$(6.2\pm2.0)\times10^{-34}\exp(T/300)^{-1.25\pm0.5}[O_2]$	200-300	O_3, Review	3
CO	$(6.5\pm4.0)\times10^{-33}\exp(-2180/T)[CO]$	250-500	CO_2, Review	1

NO	$(1.0\pm0.3)\times10^{-31}\exp(T/300)^{-1.6\pm0.5}[N_2]$	200–300	NO_2, Review	3
SO	$(1.9\pm1.0)\times10^{-31}[Ar]$	298	SO_2, Review	1
CS	$(2.7\pm0.5)\times10^{-10}\exp(-760\pm250/T)$	150–300	CO+S, Review	3
HCl	$(1.0^{+1.0}_{-0.5})\times10^{-11}\exp(-3340\pm350/T)$	293–718	HO+Cl, Review	3
O_3	$(8.0\pm1.5)\times10^{-12}\exp(-2060\pm2200/T)$	220–400	$O+O_3$, $2O_2$, Review	3
NO_2	$(9.3\pm1.4)\times10^{-12}$	230–340	$NO+O_2$, Review	3
	$(9.0\pm2.0)\times10^{-32}(T/300)^{-2.0\pm1.0}[N_2]$	200–400	NO_3, Review	3
H_2S	$(1.4^{+1.3}_{-0.6})\times10^{-11}\exp(-1920\pm750/T)$	290–500	HO+HS, Review	3
CS_2	$(3.2\pm2.0)\times10^{-11}\exp(-650\pm100/T)$	200–500	Review	3
SO_2	$(4.0\pm2.0)\times10^{-32}\exp(-1000^{+200}_{-100}/T)[N_2]$	200–400	SO_3, Review	3
HOCl	$1.0\times10^{-11}\exp(-2200\pm1000/T)$	200–300	HO+ClO, Review	3
Cl_2O	$(1.4\pm0.3)\times10^{-11}$	300	Review	1
NH_3	$(2.5\pm1.5)\times10^{-12}\exp(-3020/T)$	300–1000	$HO+NH_2$, Review	1
H_2O_2	$(1.0^{+1.0}_{-0.5})\times10^{-11}\exp(-2500\pm1000/T)$	250–370	$HO+HO_2$, Review	1
NO_3	1×10^{-11}	298	Review	1
CH_4	$(3.5\pm1.0)\times10^{-11}\exp(-4550/T)$	350–1000	CH_3+CHO, CH_2CO+H_2, Review	25
C_2H_6	$(4.2\pm0.7)\times10^{-11}\exp(-3200/T)$	298–650	Review	25
C_2H_4	$(5.5\pm1.0)\times10^{-12}\exp(-565/T)$	200–500	Review	25
C_3H_6	$(4.2\pm1.0)\times10^{-12}\exp(-38/T)$	200–500	Review	25
cis-2-Butene	$(9.8\pm2.0)\times10^{-12}\exp(+165/T)$	250–500	Review	25
2-methyl-2-butene	$(6.5\pm1.2)\times10^{-12}\exp(+680/T)$	298–400	Review	25
2,3-dimethyl-2-butene	$(5.7\pm1.2)\times10^{-12}\exp(+790/T)$	298–400	Review	25

1,3-butadiene	$(5.7\pm1.5)\times10^{-12}\exp(+380/T)$	298-400	Review	25
C_2H_2	$(2.3\pm0.5)\times10^{-11}\exp(-1500/T)$	200-700	Review	25
CH_3Cl	$(2.8\pm1.0)\times10^{-11}\exp(-3690/T)$	350-1000	Review	25
CCl_4	$(3.3\pm2.0)\times10^{-14}\exp(-2260/T)$	270-380	Review	25
CF_2CF_2	$(1.3\pm0.5)\times10^{-12}\exp(-100/T)$	298-500	Review	25
C_6H_6	$(3.3^{+3.0}_{-1.0})\times10^{-11}\exp(-2000/T)$	250-500	Review	25
$CH_3C_6H_5$	$(2.3\pm2.0)\times10^{-13}$	298	Review	25
CH_3OH	$(2.7\pm0.5)\times10^{-11}\exp(-2530\pm80/T)$	298	DF, FP-RF	26
H_2CO	$(2.94\pm0.26)\times10^{-11}\exp(-1540\pm35/T)$	250-750	OH+HCO, DF, FP-RF	27
CH_3CHO	$(2.3^{+2.0}_{-1.2})\times10^{-11}\exp(-1140/T)$	298-500	Review	25
CH_3OCH_3	$(9.8\pm3.0)\times10^{-12}\exp(-1520/T)$	200-500	Review	25
H_2CCO	$(2.92\pm0.78)\times10^{-12}\exp(-680\pm80/T)$	230-449	PR-RA	28
CH_3SCH_3	$(1.3\pm0.5)\times10^{-11}\exp(+390\pm100/T)$	270-500	Review	25
CH_3NH_2	$(9.02\pm1.0)\times10^{-12}\exp(-830\pm100/T)$	298-440	FP-CL	29

$O(^1D)$

He	$<3\times10^{-16}$	298	Quenching, Review	30
Ar	$(3\pm2)\times10^{-13}$	298	Quenching, Review	30
Xe	$(7.2\pm1.4)\times10^{-11}$	298	Quenching, Review	30
H_2	$(1.1\pm0.4)\times10^{-10}$	200-350	HO+H, $O(^3P)+H_2$ Review	3
O_2	$(3.2\pm0.3)\times10^{-11}\exp(+67/T)$	200-350	$O(^3P)+O_2(^3\Sigma g, ^1\Delta g, ^1\Sigma g^+)$ Review	3
N_2	$(1.8\pm0.4)\times10^{-11}\exp(+107\pm100/T)$	200-350	Quenching, Review	3
NO	$(4.0\pm1.0)\times10^{-11}$	298	Review	30
CO	$(3.6\pm0.5)\times10^{-11}$	298	Quenching, Review	30
HCl	$(1.3\pm0.3)\times10^{-10}$	199-375	OH+Cl, Review	30

Cl_2	$(1.8\pm1.0)\times10^{-10}$	298	Review	30
O_3	$(2.4\pm0.2)\times10^{-10}$	100-400	Review	3
H_2O	$(2.3\pm0.5)\times10^{-10}$	200-350	2OH, H_2+O_2, $O(^3P)$+H_2O, Review	3
NO_2	$(1.4\pm0.3)\times10^{-10}$	298	Review	30
CO_2	$6.8\times10^{-11}\exp(+120\pm25/T)$	200-354	Quenching, Review	30
COS	$(1.5\pm0.3)\times10^{-10}$	298	Review	30
N_2O	$(4.4\pm1.0)\times10^{-11}$	200-350	N_2+O_2, Review	3
	$(7.2\pm1.5)\times10^{-11}$	200-350	2NO, Review	3
SO_2	$(1.3\pm0.7)\times10^{-10}$	298	Review	30
NH_3	$(2.7\pm0.4)\times10^{-10}$	204-354	OH+NH_2, Review	3
H_2O_2	5.2×10^{-10}	300	OH+HO_2, Review	1
CH_4	$(1.4\pm0.3)\times10^{-10}$	200-300	HO+CH_3, Review	3
	1.5×10^{-11}	200-300	H_2CO+H_2, Review	3
neo-C_5H_{12}	$(5.2\pm1.0)\times10^{-10}$	298	Review	30
C_2H_4	$(2.2\pm0.5)\times10^{-10}$	298	P-GC	31
C_3H_6	$(6.0\pm1.2)\times10^{-10}$	298	insertion, P-GC	31
cis-2-butene	$(8.7\pm1.8)\times10^{-10}$	298	P-GC	31
2-methyl-2-butene	$(1.1\pm0.2)\times10^{-9}$	298	P-GC	31
CF_3H	$(5.4\pm1.1)\times10^{-11}$	298	Review	30
CF_4	$(1.7\pm0.3)\times10^{-11}$	298	Review	30
CF_2Cl_2	$(1.4\pm0.3)\times10^{-10}$	298	Review	3
$CFCl_3$	$(2.3\pm0.6)\times10^{-10}$	298	Review	3
CCl_4	$(3.3\pm0.8)\times10^{-10}$	298	Review	3
C_2F_6	$<5\times10^{-12}$	298	Review	30
C_2F_4	$(2^{+2}_{-1})\times10^{-10}$	298	Review	30
CH_3OH	$(6.6\pm3.4)\times10^{-10}$	298	OH+CH_3O(50%), Review	30

$O(^1S)$

O	$(5.0\pm3.0)\times10^{-11}\exp(-300/T)$	200-370	Quenching, Review	30
N	$<1\times10^{-12}$	298	Review	30
He	$\sim7\times10^{-20}$	298	Quenching, Review	30
Ar	$(4.8\pm1.0)\times10^{-18}$	200-380	Quenching, Review	30
Xe	$(7\pm3)\times10^{-16}\exp(+380/T)$	200-300	Quenching, Review	30
H_2	$(2.6\pm2.0)\times10^{-16}$	298	Review	30
O_2	$(4.8\pm2.0)\times10^{-12}\exp(-850/T)$	200-450	Review	30
N_2	$\leq5\times10^{-17}$	200-380	Review	30
NO	$(3.3\pm0.1)\times10^{-11}T^{0.5}$	200-300	Review	30
CO	$(9.4\pm8,5)\times10^{-14}$	298	Quenching, Review	30
O_3	$(5.8\pm1.2)\times10^{-10}$	298	Review	30
H_2O	$(5.0\pm4.0)\times10^{-10}$	298	Review	30
NO_2	$(5.0\pm2.0)\times10^{-10}$	298	Review	30
N_2O	$(3.8\pm1.0)\times10^{-11}\exp(-420/T)$	200-370	Review	30
CO_2	$(3.0\pm1.0)\times10^{-11}\exp(-1320/T)$	150-500	Review	30
NH_3	$(5.0\pm2.0)\times10^{-10}$	298	Review	30
CH_4	$(2.7\pm2.0)\times10^{-14}$	298	Review	30
C_2H_6	1.0×10^{-12}	298	Review	30
C_2H_4	1.0×10^{-9}	298	Review	30
C_3H_6	8×10^{-10}	298	Review	30
C_2H_2	9×10^{-10}	298	Review	30

$Si(^3P)$

H_2	10^{-33}[He]	300	FP-RA	32
N_2	4×10^{-32}[He]	300	FP-RA	32
O_2	$(2.7\pm0.3)\times10^{-10}$	300	FP-RA	33
	$(9.8\pm4.9)\times10^{-12}$	300	DF-RA	34
F_2	$(1.2\pm0.5)\times10^{-11}$	300	FP-RA	35
	$(1.2\pm0.6)\times10^{-10}$	600	DF-RA	36
Cl_2	$(3.3\pm0.3)\times10^{-10}$	300	FP-RA	32

CO	$<3\times10^{-33}$	300	FP-RA	32
NO	$(1.1\pm0.1)\times10^{-10}$	300	FP-RA	32
	$(2.0\pm1.0)\times10^{-11}$	300	DF-RA	34
CO_2	$(1.1\pm0.1)\times10^{-11}$	300	FP-RA	32
N_2O	$(1.9\pm0.2)\times10^{-10}$	300	FP-RA	33
	$(8.2\pm4.1)\times10^{-11}$	300	DF-RA	34
CH_4	$<10^{-14}$	300	FP-RA	32
C_2H_4	$(2.2\pm0.2)\times10^{-10}$	300	FP-RA	32
C_2H_2	$(4.9\pm0.3)\times10^{-10}$	300	FP-RA	32
CF_4	$(2.4\pm0.3)\times10^{-12}$	300	FP-RA	32
$SiCl_4$	$(7.2\pm1.2)\times10^{-11}$	300	FP-RA	33
$Si(^1D)$				
He	$\leq10^{-15}$	300	FP-RA	37
Kr	$<4\times10^{-15}$	300	FP-RA	38
Xe	$<6\times10^{-15}$	300	FP-RA	38
H_2	8.1×10^{-11}	300	FP-RA	37
N_2	$\leq5\times10^{-12}$	300	FP-RA	38
O_2	2.3×10^{-11}	300	FP-RA	37
F_2	$(8.2\pm2.1)\times10^{-11}$	300	FP-RA	35
Cl_2	6.1×10^{-11}	300	FP-RA	38
CO	1.1×10^{-11}	300	FP-RA	38
NO	7.1×10^{-11}	300	FP-RA	38
CO_2	1.7×10^{-11}	300	FP-RA	38
N_2O	1.7×10^{-11}	300	FP-RA	38
CH_4	1.3×10^{-10}	300	FP-RA	38
C_2H_4	3.7×10^{-10}	300	FP-RA	38

C_2H_2	2.0×10^{-10}	300	FP-RA	38
CF_4	$\leq4.2\times10^{-12}$	300	FP-RA	38
$SiCl_4$	2.9×10^{-10}	300	FP-RA	37

$Si(^1S)$

He	$\leq1.3\times10^{-15}$	300	FP-RA	39
Kr	$<4\times10^{-15}$	300	FP-RA	38
Xe	$<6\times10^{-15}$	300	FP-RA	38
H_2	$\leq10^{-14}$	300	FP-RA	40
N_2	$\leq10^{-14}$	300	FP-RA	40
O_2	$(1.5\pm0.2)\times10^{-11}$	300	FP-RA	39
F_2	$(1.9\pm0.8)\times10^{-10}$	300	FP-RA	35
Cl_2	$(7.3\pm0.1)\times10^{-11}$	300	FP-RA	40
CO	$\leq10^{-14}$	300	FP-RA	40
NO	$(1.2\pm0.05)\times10^{-9}$	300	FP-RA	40
CO_2	$(1.7\pm0.3)\times10^{-11}$	300	FP-RA	39
N_2O	$(4.3\pm0.4)\times10^{-11}$	300	FP-RA	39
CH_4	$(9.4\pm1.2)\times10^{-11}$	300	FP-RA	40
C_2H_4	$(2.5\pm0.3)\times10^{-10}$	300	FP-RA	40
C_2H_2	$(1.1\pm0.1)\times10^{-10}$	300	FP-RA	40
CF_4	$(4.3\pm0.8)\times10^{-12}$	300	FP-RA	40
$SiCl_4$	$(9.1\pm1.4)\times10^{-11}$	300	FP-RA	39

$S(^3P)$

OH	$(6.6\pm1.4)\times10^{-11}$	300	SO+H, DF-EPR	41
O_2	$(1.7\pm0.5)\times10^{-12}\exp(+153\pm108/T)$	296-410	SO+O, DF-RF	42
F_2	$(2.9\pm0.8)\times10^{-13}$	298	DF-RF	43

Cl_2	$(1.1\pm0.1)\times10^{-11}$	298	DF-RF	43
NO	$(5.3\pm0.3)\times10^{-31}[CO_2]$	298	SNO, FP-A	44
O_3	$(1.2\pm0.3)\times10^{-11}$	298	DF-RF	43
NO_2	$(6.2\pm1.4)\times10^{-11}$	298	SO+NO, DF-RF	43
	$(4.9\pm1.0)\times10^{-11}\exp(+84\pm60/T)$	296-410	DF-RF	42
OCS	$(1.52\pm0.20)\times10^{-12}\exp(-1826\pm60/T)$	233-445	$CO+S_2$, FP-RF	45
CS_2	$(6.5\pm4.0)\times10^{-13}$	298	Review	1
C_2H_4	1.2×10^{-12}	298	FP-A	46
	$(7.13\pm0.74)\times10^{-12}\exp(-795\pm40/T)$	219-500	C_2H_4S, FP-RF	47
C_3H_8	$(6.03\pm0.72)\times10^{-12}\exp(-191\pm45/T)$	214-500	FP-RF	48
1-Butene	$(7.41\pm1.15)\times10^{-12}\exp(-181\pm45/T)$	216-475	FP-RF	48
	$(1.5\pm0.17)\times10^{-11}$	298	FP-A	49
cis-2-Butene	$(4.68\pm0.70)\times10^{-12}\exp(+116\pm45/T)$	219-500	FP-RF	50
2,3-dimethyl-2-butene	$(4.68\pm1.70)\times10^{-12}\exp(+649\pm116/T)$	252-500	FP-RF	50
	$(1.0\pm0.1)\times10^{-10}$	298	FP-A	49
C_2H_2	$(5.0\pm0.5)\times10^{-13}$	295	C_2H_2S, FP-RA	51
Thiirane	$(4.47\pm0.26)\times10^{-11}$	298-355	$C_2H_4+S_2$, FP-RF	52
	$(2.3\pm0.3)\times10^{-11}$	298	$C_2H_4+S_2$, FP-A	53

$S(^1D)$

He	$<4.4\times10^{-14}$	300	FP-RA	54
Ar	$\geq1.9\times10^{-12}$	300	FP-RA	54
Xe	$\geq6.7\times10^{-12}$	300	FP-RA	54
H_2	$\geq1.75\times10^{-11}$	300	FP-RA	54
N_2O	$\geq2.2\times10^{-10}$	300	NS+NO, FP-RA	55
OCS	$(3.0\pm0.3)\times10^{-10}$	295	S_2+CO, FP-RF	56
	$(1.2\pm1.0)\times10^{-10}$	300	FP-RA	57

CS_2	$(3.5\pm1.0)\times10^{-10}$	295	FP-RF	56
	$(1.5\pm0.3)\times10^{-10}$	300	FP-RA	57
CH_4	$(1.8\pm0.5)\times10^{-10}$	295	FP-RF	56
	$(1.2\pm0.3)\times10^{-10}$	300	FP-RA	57

$S(^1S)$

O	$(5.0\pm3.0)\times10^{-11}\exp(-307\pm191/T)$	200-365	FQ	58
	$(7.5\pm0.8)\times10^{-12}$	300	FQ	59
He	$<1.25\times10^{-15}$	300	FP-RA	54
	$\leq6\times10^{-18}$	296	FQ	60
Ar	$<5\times10^{-15}$	300	FP-RA	54
	$\leq6\times10^{-18}$	296	FQ	60
	$<(3.5\pm1.5)\times10^{-17}$	298	FQ	61
Xe	$<10^{-13}$	300	FP-RA	54
	$\leq1.6\times10^{-16}$	296	FQ	60
H_2	$(4.0\pm1.0)\times10^{-15}$	300	FP-RA	62
	$\leq(8.6\pm0.9)\times10^{-16}$	296	FQ	60
	$(7.7\pm1.5)\times10^{-16}$	298		61
N_2	$\leq1\times10^{-17}$	296	FQ	60
O_2	$(6.0\pm0.6)\times10^{-13}$	298	FQ	61
CO	$\leq(3.5\pm0.7)\times10^{-16}$	298	FQ	61
NO	$(3.2\pm0.4)\times10^{-10}$	298	FQ	61
NO_2	$(6.1\pm0.6)\times10^{-10}$	298	FQ	61
N_2O	$<3\times10^{-15}$	298	FQ	61
CO_2	$<6\times10^{-17}$	298	FQ	61
OCS	$(4\pm2)\times10^{-13}$	298	FQ	61
	1.0×10^{-11}	300	FP-RA	62

CS_2	$(8.1\pm0.8)\times10^{-10}$	298	FQ	61
SO_2	$(1.0\pm0.2)\times10^{-10}$	298	FQ	61
H_2S	$(4.9\pm0.5)\times10^{-10}$	298	FQ	61
CH_4	$(1.5\pm0.2)\times10^{-15}$	298	FQ	61
C_2H_6	$(4.4\pm0.5)\times10^{-14}$	298	FQ	61
C_2H_4	$(1.3\pm0.2)\times10^{-13}$	298	FQ	61
C_2H_2	$(1.6\pm0.2)\times10^{-13}$	298	FQ	61

F

F	$8.0\times10^{-34}[N_2]$	295	F_2, Review	63
H_2	$(1.9\pm0.5)\times10^{-10}\exp(-570\pm150/T)$	190–770	HF+H, Review	3
O_2	$(1.3\pm0.8)\times10^{-32}(T/300)^{-1.4\pm1.0}[N_2]$	200–300	FO_2, Review	3
Cl_2	$(1.1\pm0.4)\times10^{-10}$	298	ClF+Cl, DF-MS	64
Br_2	$(2.2\pm1.1)\times10^{-10}$	300	BrF+Br, DF-RA	65
HCl	2.5×10^{-11}	298	FH+Cl, DF-A(L)	66
	$4.2\times10^{-11}\exp(-450/T)$		Review	67
H_2O	$(4.2^{+8.0}_{-3.0})\times10^{-11}\exp(-400\pm200/T)$	240–370	HF+HO, Review	3
NO_2	$k_0=(9.8\pm1.6)\times10^{-31}[N_2]$ $k_\infty=(3.2\pm0.8)\times10^{-11}$	298	FONO, IRMPD	69
O_3	$2.8\times10^{-11}\exp(-230\pm200/T)$	298	$FO+O_2$, DF-MS	68
COS	$(2.52\pm0.19)\times10^{-11}$	295	SF+CO, DF-MS	70
CH_4	$(3.0\pm2.0)\times10^{-10}\exp(-400\pm150/T)$	250–450	$HF+CH_3$, Review	3
CH_3Cl	$(2.4\pm0.7)\times10^{-11}$	298	$HF+CH_2Cl$, DF-MS	64
$CHCl_3$	$(0.63\pm0.14)\times10^{-11}$	298	$HF+CCl_3$, DF-MS	64
CHF_3	$0.63\times10^{-11}\exp(-1210/T)$	301–667	$HF+CF_3$, DF-MS	64

$Cl(^2P_{3/2})$

Cl	$6.32\times10^{-34}\exp(908\pm55/T)[Ar]$	195-514	Cl_2, Review	71
HO_2	$(1.8\pm1.0)\times10^{-11}\exp(+170\pm250/T)$	250-420	$HCl+O_2$, Review	3
H_2	$(3.7\pm1.0)\times10^{-11}\exp(-2300\pm200/T)$	200-300	HCl+H, Review	3
NO	$(1.1\pm0.2)\times10^{-31}[N_2]$	293	ClNO, Review	71
	$(1.18\pm0.10)\times10^{-32}\exp(532\pm20/T)[N_2]$	200-400	FP-RF	72
HBr	$(7.4\pm0.7)\times10^{-12}$	295	HCl+Br, LP-CL(IR)	73
HI	$(1.6\pm0.1)\times10^{-10}$	295	HCl+I, LP-CL(IR)	73
BrCl	$(1.45\pm0.2)\times10^{-11}$	298	Cl_2+Br, DF-CL	74
Br_2	$(1.9\pm0.2)\times10^{-10}$	298	BrCl+Br, DF-RA	75
O_3	$(2.7\pm0.4)\times10^{-11}\exp(-257\pm100/T)$	205-298	$ClO+O_2$, Review	3
NO_2	$(1.48\pm0.4)\times10^{-30}[N_2]$	296	$ClNO_2$, DF-RF	76
HOCl	$3\times10^{-12}\exp(-150/T)$	200-300	HCl+ClO, Review	3
ClO_2	$(5.9\pm0.9)\times10^{-11}\exp(-0\pm120/T)$	298-588	2ClO, Review	71
Cl_2O	6.8×10^{-13}	300	Cl_2+ClO, Review	71
	$(9.8\pm0.8)\times10^{-11}$	298	Cl_2+ClO, DF-RF, MS	77
ClNO	$(3.0\pm0.5)\times10^{-11}$	298	Cl_2+NO, Review	71
H_2S	$(6.0\pm1.2)\times10^{-12}$	296	HCl+HS, LP-CL(IR)	78
	$(5.1\pm0.7)\times10^{-11}$	296	HCl+HS, DF-MS	79
OCS	$<4\times10^{-15}$	298	CO+SCl, DF-MS	79
SO_2	$(2.3\pm0.5)\times10^{-33}[N_2]$	295	$ClSO_2$, DF-MS	80
H_2O_2	$(1.1\pm0.5)\times10^{-11}\exp(-980\pm500/T)$	265-424	$HCl+HO_2$, Review	3
HNO_3	$\leq1.7\times10^{-14}$	298	$HCl+NO_3$, Review	3
	$5.1\times10^{-12}\exp(-1700/T)$	240-300	FP-RF	81
$ClONO_2$	$6.8\times10^{-12}\exp(+160\pm200/T)$	219-298	Review	3
	$7.3\times10^{-12}\exp(165/T)$	220-296	FP-RF	82

CH_4	$(9.6\pm2.5)\times10^{-12}\exp(-1350\pm250/T)$	200-300	$HCl+CH_3$, Review	3
C_2H_6	$(7.7\pm1.0)\times10^{-11}\exp(-90\pm100/T)$	220-350	$HCl+C_2H_5$, Review	3
CH_3F	$(4.79\pm1.05)\times10^{-12}\exp(-772\pm54/T)$	216-296	$HCl+CH_2F$, FP-RF	83
CH_3Cl	$(3.4\pm0.8)\times10^{-11}\exp(-1260\pm200/T)$	233-350	$HCl+CH_2Cl$, Review	3
$CHCl_3$	$(1.23\pm0.34)\times10^{-13}$	298	$HCl+CCl_3$, Review	71
CH_3CH_2Cl	$(2.34\pm0.42)\times10^{-11}\exp(-310\pm56/T)$	257-426	LP-RF	84
CH_3CHCl_2	$(8.19\pm1.84)\times10^{-12}\exp(-554\pm71/T)$	257-426	LP-RF	84
CH_2ClCH_2Cl	$(2.21\pm0.51)\times10^{-11}\exp(-793\pm73/T)$	257-426	LP-RF	84
$CH_2ClCHCl_2$	$(4.88\pm1.41)\times10^{-12}\exp(-786\pm88/T)$	257-426	LP-RF	84
H_2CO	$(7.9\pm1.1)\times10^{-11}\exp(-34\pm100/T)$	200-500	HCl+HCO, Review	3
CH_3OH	$(6.33\pm0.70)\times10^{-11}$	200-500	$HCl+CH_2OH$, FP-RF	85
CH_3OCH_3	$(1.76\pm0.15)\times10^{-10}$	200-500	FP-RF	85
CH_3OOCH_3	$(1.20\pm0.26)\times10^{-10}$	220-330	FP-RF	86
CH_3CN	$\leq2\times10^{-15}$	298	FP-RF	87
	$(8.89\pm1.24)\times10^{-15}$	295	DF-ESR-MS	88
	$(3.46\pm0.70)\times10^{-11}\exp(-2785\pm115/T)$	295-723	DF-ESR-MS	88
SiH_4	$(9.2\pm2.0)\times10^{-11}$	298	DF-RF	89
GeH_4	$(2.4\pm1.8)\times10^{-10}$	298	DF-RF	89
AsH_3	$>2.0\times10^{-10}$	298	DF-RF	89
$Cl(^2P_{1/2})$				
He	$(3.8\pm0.6)\times10^{-15}$	300	$Cl(^2P_{3/2})$, FP-RA	90
Ne	$(4.0\pm0.5)\times10^{-14}$	300	FP-RA	91
Ar	$(1.1\pm0.3)\times10^{-12}$	300	FP-RA	91
Kr	$(1.4\pm0.2)\times10^{-12}$	300	FP-RA	91
Xe	$(1.8\pm0.2)\times10^{-11}$	300	FP-RA	91

H	$7x10^{-11}$	300	FP-RA	92
H_2	$<6x10^{-13}$	300	FP-RA	93
N_2	$(6.3\pm1.0)x10^{-13}$	300	FP-RA	93
O_2	$(2.3\pm0.3)x10^{-11}$	300	FP-RA	93
Cl_2	$(4.5\pm0.4)x10^{-11}$	300	FP-RA	90
HCl	$(1.1\pm0.1)x10^{-12}$	300	FP-RA	93
CO	$6x10^{-12}$	300	FP-RA	93
CO_2	$<5x10^{-13}$	300	FP-RA	93
N_2O	$(3.7\pm0.6)x10^{-13}$	300	FP-RA	93
H_2O	$(2.6\pm0.5)x10^{-12}$	300	FP-RA	93
CH_4	$(3.9\pm0.8)x10^{-12}$	300	FP-RA	93
CCl_4	$(2.1\pm0.4)x10^{-10}$	300	FP-RA	94
$CFCl_3$	$(3.1\pm0.6)x10^{-10}$	300	FP-RA	94
CF_2Cl_2	$(2.1\pm0.4)x10^{-10}$	300	FP-RA	94
CF_3Cl	$(2.2\pm0.4)x10^{-10}$	300	FP-RA	94
CF_4	$(1.5\pm0.4)x10^{-10}$	300	FP-RA	94

$Br(^2P_{3/2})$

HO_2	$2.2x10^{-13}$	298	DF-MS	95
ICl	$(3.0\pm0.8)x10^{-14}$	298	BrCl+I, DF-CL	73
IBr	$(3.5\pm0.6)x10^{-11}$	298	Br_2+I, DF-CL	73
O_3	$(1.4\pm0.3)x10^{-11}exp(-760\pm200/T)$	220-360	BrO+O_2, Review	3
ClNO	$(1.0\pm0.2)x10^{-11}$	298	BrCl+NO, Review	67
H_2O_2	$\leq2x10^{-15}$	298	HBr+HO_2, Review	3
	$<3x10^{-15}$	298-417	DF-MS	96
H_2CO	$(1.7\pm0.8)x10^{-11}exp(-800\pm250/T)$	223-480	HBr+HCO, Review	3

$Br(^2P_{1/2})$				
Cl_2	$(2.2\pm1.4)\times10^{-14}$	298	LP-FQ(IR)	97
BrCl	$(2.9\pm1.4)\times10^{-14}$	298	LP-FQ(IR)	97
Br	$(4.7\pm0.4)\times10^{-13}$	298	LP-FQ(IR)	97
ICl	$(9\pm4)\times10^{-13}$	298	LP-FQ(IR)	97
IBr	$(1.00\pm0.14)\times10^{-12}$	298	LP-FQ(IR)	97
I_2	$(1.86\pm0.37)\times10^{-12}$	298	LP-FQ(IR)	97
$I(^2P_{3/2})$				
I	$(7.4\pm2.0)\times10^{-33}[Ar]$	298	I_2, PF-A	98
NO	$(1.8\pm0.5)\times10^{-32}(T/300)^{-1.0\pm0.5}[N_2]$	200-400	INO, Review	3
NO_2	$(2.9^{+3.0}_{-1.5})\times10^{-31}(T/300)^{-1.0\pm0.5}[N_2]$	298-450	INO_2, Review	3
O_3	$1.0\times10^{-12\pm1.0}$	298	$IO+O_2$, Review	3
$I(^2P_{1/2})$				
Cl_2	$(2.5\pm0.9)\times10^{-12}\exp(-1600\pm300/T)$	200-400	ICl+Cl, FP-RF	99
Br_2	$(4.0\pm1.5)\times10^{-11}\exp(-400\pm300/T)$	200-400	IBr+Br, FP-RF	99
ICl	$(1.6\pm0.3)\times10^{-11}$	300	I_2+Cl, FP-RF	99
IBr	$(2.0\pm1.0)\times10^{-11}$	300	I_2+Br, FP-RF	99
HCl	$(4.4\pm0.9)\times10^{-14}\exp(-290\pm70/T)$	200-400	FP-RA	100
HBr	$(1.3\pm0.1)\times10^{-13}$	295	FP-RA	101
HI	$(5.2\pm0.4)\times10^{-14}$	293	FP-RA	101
H_2O	$(8.4\pm1.1)\times10^{-13}$	293	FP-RA	101
D_2O	$(1.8\pm0.4)\times10^{-14}$	293	FP-RA	101
HCN	$(6.8\pm0.7)\times10^{-14}$	295	FP-RF	102

NH_3	$(2.1\pm0.2)\times10^{-13}$	295	FP-RF	102
OCS	$(1.6\pm0.1)\times10^{-14}$	295	FP-RF	102
CH_4	$(9.4\pm0.4)\times10^{-14}$	295	FP-RF	103
CD_3H	$(5.4\pm0.4)\times10^{-14}$	295	FP-RF	103
CD_4	$(2.2\pm0.4)\times10^{-15}$	295	FP-RF	103
C_2D_4	$(3.1\pm0.2)\times10^{-15}$	295	FP-RF	104
C_3D_6	$(4.6\pm0.4)\times10^{-15}$	295	FP-RF	104
CH_3I	$(6.2\pm1.4)\times10^{-13}$	298	FP-RA	105
	$(2.8\pm0.22)\times10^{-13}$	298	FP-RF	106
CD_3I	$(4.2\pm0.2)\times10^{-15}$	295	FP-RF	104
CF_3I	$(3.5\pm0.6)\times10^{-16}$	298	FP-RA	105
	$(3.5\pm0.5)\times10^{-17}$	298	FP-RF	106
C_2H_5I	$(6.2\pm1.4)\times10^{-13}$	298	FP-RA	105
	$(2.85\pm0.40)\times10^{-13}$	298	FP-RF	106

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Table 3-2 Rate Constants for radicals of group II

Reactant	Rate constant ($cm^3 molecule^{-1} s^{-1}$)	Temp. (K)	Comments	Ref.
$C_2(X^1\Sigma_g^+)$				
H_2	$(1.38\pm0.6)\times10^{-12}$	298	MPD-LIF	1
	$(1.4\pm0.2)\times10^{-12}$	300	IRMPD-LIF	2
	$(1.8\pm1.0)\times10^{-10}\exp(-1470\pm220/T)$	295-493	MPD-LIF	3
N_2	$<3\times10^{-14}$	300	IRMPD-LIF	2
O_2	$(2.82\pm0.09)\times10^{-12}$	298	MPD-LIF	1
NO	$(2.1\pm0.3)\times10^{-10}$	300	IRMPD-LIF	2
CO_2	$<3\times10^{-14}$	300	IRMPD-LIF	2
H_2O	$<3\times10^{-14}$	300	IRMPD-LIF	2
CH_4	$(1.87\pm0.05)\times10^{-11}$	298	MPD-LIF	1
	$(1.7\pm0.2)\times10^{-11}$	300	IRMPD-LIF	2
	$(5.05\pm0.15)\times10^{-11}\exp(-300\pm10/T)$	298-517	MPD-LIF	3
CF_4	$<3\times10^{-14}$	300	IRMPD-LIF	2
C_2H_6	$(1.59\pm0.05)\times10^{-10}$	298	MPD-LIF	1
C_3H_8	$(3.3\pm0.2)\times10^{-10}$	300	IRMPD-LIF	2
C_2H_4	$(3.26\pm0.05)\times10^{-10}$	298	MPD-LIF	1
C_2H_3F	$(2.0\pm0.2)\times10^{-10}$	300	IRMPD-LIF	2
C_2F_4	$(5.99\pm0.14)\times10^{-11}$	298	MPD-LIF	1
C_2H_3Cl	$(4.9\pm0.4)\times10^{-10}$	300	IRMPD-LIF	2
C_2HCl_3	$(2.4\pm0.2)\times10^{-10}$	300	IRMPD-LIF	2
C_2Cl_4	$(2.6\pm0.2)\times10^{-10}$	300	IRMPD-LIF	2
C_2H_2	$(4.3\pm0.4)\times10^{-10}$	300	IRMPD-LIF	2
CH_3C_2H	$(4.7\pm0.4)\times10^{-10}$	300	IRMPD-LIF	2
C_6H_6	$(5.2\pm0.4)\times10^{-10}$	300	IRMPD-LIF	2
C_2H_3CN	$(4.4\pm0.3)\times10^{-10}$	300	IRMPD-LIF	2

$C_2(a^3\Pi u)$

Ar	$<3\times10^{-14}$	300	IRMPD-LIF	2
Kr	$(2.0\pm0.2)\times10^{-13}$	300	IRMPD-LIF	2
Xe	$(4.5\pm0.4)\times10^{-12}$	300	IRMPD-LIF	2
	$(5.54\pm0.44)\times10^{-12}\exp(24\pm30/T)$	300-600	MPD-LIF	4
H_2	$<5\times10^{-15}$	298	MPD-LIF	1
	$(1.55\pm0.10)\times10^{-11}\exp(-3012\pm31/T)$	300-600	MPD-LIF	4
D_2	$(1.80\pm0.22)\times10^{-11}\exp(-3710\pm72/T)$	300-600	MPD-LIF	4
N_2	$<3\times10^{-14}$	300	IRMPD-LIF	2
O_2	$(2.96\pm0.07)\times10^{-12}$	298	MPD-LIF	5
	$(2.7\pm0.3)\times10^{-11}$	300	IRMPD-LIF	6
NO	$(7.5\pm0.3)\times10^{-11}$	300	IRMPD-LIF	7
CO_2	$<3\times10^{-14}$	300	IRMPD-LIF	2
H_2O	$<3\times10^{-14}$	300	IRMPD-LIF	2
CH_4	$<1\times10^{-16}$	298	MPD-LIF	5
	$(1.65\pm0.20)\times10^{-11}\exp(-2800\pm55/T)$	300-600	MPD-LIF	8
CF_4	$<3\times10^{-14}$	300	IRMPD-LIF	2
C_2H_6	$(1.30\pm0.06)\times10^{-12}$	298	MPD-LIF	5
	$(2.42\pm0.10)\times10^{-11}\exp(-919\pm15/T)$	300-600	MPD-LIF	4
C_3H_8	$(1.66\pm0.10)\times10^{-10}$	300	IRMPD-LIF	2
	$(1.84\pm0.17)\times10^{-11}\exp(-97\pm36/T)$	300-600	MPD-LIF	4
n-C_4H_{10}	$(4.9\pm0.5)\times10^{-11}\exp(-71\pm41/T)$	300-600	MPD-LIF	4
C_2H_4	$(1.44\pm0.06)\times10^{-10}$	298	MPD-LIF	5
	$(1.7\pm0.2)\times10^{-10}$	300	IRMPD-LIF	2
	$(1.20\pm0.16)\times10^{-10}\exp(5\pm46/T)$	300-600	MPD-LIF	4
C_2H_3F	$(7.6\pm0.5)\times10^{-11}$	300	IRMPD-LIF	2
C_2H_3Cl	$(1.22\pm0.09)\times10^{-10}$	300	IRMPD-LIF	2
C_2HCl_3	$(3.8\pm0.2)\times10^{-11}$	300	IRMPD-LIF	2
C_2Cl_4	$(6\pm0.5)\times10^{-13}$	300	IRMPD-LIF	2
C_2H_2	$(9.6\pm0.3)\times10^{-11}$	298	MPD-LIF	5
CH_3C_2H	$(2.6\pm0.2)\times10^{-10}$	300	IRMPD-LIF	2

C_6H_6	$(7.6\pm0.4)\times10^{-11}$	300	IRMPD-LIF	2
C_2H_3CN	$(5.7\pm0.4)\times10^{-11}$	300	IRMPD-LIF	2
$C_3(X^1\Sigma_g^+)$				
O_2	$\leq1.5\times10^{-14}$	298	IRMPD-LIF	9
NO	2.1×10^{-13}	298	IRMPD-LIF	9
C_2H_4	$<1\times10^{-15}$	294	MPD-LIF	10
	$(1.71\pm0.52)\times10^{-12}\exp(-3277\pm164/T)$	295-610	MPD-LIF	11
C_3H_6	$(5.04\pm0.31)\times10^{-14}$	294	MPD-LIF	10
	$(1.04\pm0.06)\times10^{-13}\exp(-159\pm21/T)$	295-610	MPD-LIF	11
1-C_4H_8	$(9.17\pm0.61)\times10^{-14}$	294	MPD-LIF	10
	$(1.22\pm0.05)\times10^{-13}\exp(-139\pm17/T)$	295-610	MPD-LIF	11
cis-C_4H_8	$(4.16\pm0.14)\times10^{-13}$	294	MPD-LIF	10
	$(2.10\pm0.10)\times10^{-13}\exp(201\pm18/T)$	295-610	MPD-LIF	11
iso-C_4H_8	$(4.83\pm0.19)\times10^{-12}$	294	MPD-LIF	10
	$(4.20\pm0.17)\times10^{-13}\exp(759\pm15/T)$	295-610	MPD-LIF	11
2-M-2B[a]	$(1.49\pm0.10)\times10^{-11}$	294	MPD-LIF	10
	$(5.57\pm0.45)\times10^{-13}\exp(1014\pm30/T)$	295-610	MPD-LIF	11
TME[b]	$(2.10\pm0.18)\times10^{-12}\exp(917\pm37/T)$	295-610	MPD-LIF	11
C_2H_2	$<1\times10^{-15}$	294	MPD-LIF	10
	$(9.09\pm2.67)\times10^{-12}\exp(-4065\pm163/T)$	295-610	MPD-LIF	11
CH_3C_2H	$(3.29\pm0.07)\times10^{-13}$	294	MPD-LIF	10
	$(4.93\pm0.46)\times10^{-13}\exp(-121\pm35/T)$	295-610	MPD-LIF	11
1-C_5H_8	$(5.59\pm0.31)\times10^{-13}$	294	MPD-LIF	10
2-C_6H_{10}	$(6.66\pm0.30)\times10^{-12}$	294	MPD-LIF	10
	$(1.08\pm0.01)\times10^{-13}\exp(695\pm28/T)$	295-610	MPD-LIF	11
allene	$(8.9\pm0.6)\times10^{-14}$	294	MPD-LIF	10
	4.3×10^{-13}	298	IRMPD-LIF	9
2,3-PDE[c]	$(1.07\pm0.09)\times10^{-12}$	294	MPD-LIF	10
2,4-MPD[d]	$(5.23\pm1.57)\times10^{-12}$	294	MPD-LIF	10

$CH(X^2\Pi)$

$O(^3P)$	$(9.5\pm1.4)\times10^{-11}$	298	IRMPD-LIF	12
$N(^4S)$	$(2.1\pm0.5)\times10^{-10}$	298	IRMPD-LIF	12
H_2	$0.7\sim4.5\times10^{-11}$, $25\sim600$ Torr Ar	297	LP-LIF	13
	$(2.37\pm0.43)\times10^{-12}\exp(524\pm43/T)$	159-400	at 100 Torr Ar, LP-LIF	13
N_2	$2.0\sim19.2\times10^{-13}$, $25\sim787$ Torr Ar	297	LP-LIF	14
	$(1.7\pm0.3)\times10^{-14}\exp(981\pm65/T)$	297-675	at 100 Torr Ar, LP-LIF	14
O_2	$(5.9\pm0.8)\times10^{-11}$	298	LP-LIF	15
	$(3.3\pm0.4)\times10^{-11}$	298	IRMPD-LIF	16
	$(8\pm3)\times10^{-11}$	298	CL	17
CO	$(2.1\pm0.3)\times10^{-11}$	298	LP-LIF	15
NO	$(2.9\pm0.7)\times10^{-10}$	298	LP-LIF	15
	$(2.0\pm0.3)\times10^{-10}$	300	IRMPD-LIF	18
	$(2.5\pm0.5)\times10^{-10}$	298	CL	17
CO_2	$(1.9\pm0.4)\times10^{-12}$	298	LP-LIF	15
N_2O	$(7.8\pm1.4)\times10^{-11}$	300	IRMPD-LIF	18
NO_2	$(1.67\pm0.11)\times10^{-10}$	300	IRMPD-LIF	18
CH_4	$(1.02\pm0.04)\times10^{-10}$	298	LP-LIF	19
	$(5.0\pm0.5)\times10^{-11}\exp(200\pm31/T)$	167-652	LP-LIF	19
C_2H_6	$(2.7\pm0.2)\times10^{-10}$	298	LP-LIF	19
	$(1.8\pm0.2)\times10^{-10}\exp(132\pm30/T)$	162-650	LP-LIF	19
C_3H_8	$(3.7\pm0.6)\times10^{-10}$	298	LP-LIF	19
$n-C_4H_{10}$	$(4.8\pm0.5)\times10^{-10}$	298	LP-LIF	19
	$(4.4\pm0.8)\times10^{-10}\exp(28\pm60/T)$	257-653	LP-LIF	19
$c-C_3H_6$	$(2.4\pm0.7)\times10^{-10}$	298	LP-LIF	15
$c-C_6H_{12}$	$(4.6\pm1.9)\times10^{-10}$	298	LP-LIF	15
C_2H_4	$(2.1\pm0.8)\times10^{-10}$	298	LP-LIF	15
C_2H_2	$(2.2\pm0.4)\times10^{-10}$	298	LP-LIF	15

CH_3C_2H	$(4.6\pm1.5)\times10^{-10}$	298	LP-LIF	15
C_6H_6	$(7.9\pm3.2)\times10^{-11}$	298	LP-LIF	15
$CH(A^2\Delta)$				
H_2	$(9.0\pm0.8)\times10^{-12}$	298	MPD-FQ	20
N_2	$(2.8\pm0.3)\times10^{-11}$	333	DF-FQ	21
O_2	$(1.6\pm0.1)\times10^{-11}$	298	MPD-FQ	20
CO	$(5.2\pm0.3)\times10^{-11}$	298	MPD-FQ	20
NO	$(1.04\pm0.04)\times10^{-10}$	298	MPD-FQ	20
N_2O	$(4.6\pm1.0)\times10^{-12}$	298	MPD-FQ	20
CH_4	$(2.0\pm0.1)\times10^{-11}$	298	MPD-FQ	20
C_2H_6	$(1.10\pm0.05)\times10^{-10}$	298	MPD-FQ	20
C_3H_8	$(1.7\pm0.1)\times10^{-10}$	298	MPD-FQ	20
$n\text{-}C_4H_{10}$	$(2.4\pm0.2)\times10^{-10}$	298	MPD-FQ	20
C_2H_4	$(1.9\pm0.1)\times10^{-10}$	298	MPD-FQ	20
C_2H_2	$(1.9\pm0.1)\times10^{-10}$	298	MPD-FQ	20
$CH_2(\tilde{X}^3B_1)$				
CH_2	$(5.3\pm1.5)\times10^{-11}$	298	FP-A(UV)	22
CH_3	$(1.0\pm0.1)\times10^{-10}$	298	FP-GC	23
	5.0×10^{-11}	298	FP-GC	24
H_2	$<5\times10^{-15}$	298	FP-GC	25
O_2	1.2×10^{-12}	298	FP-GC	25
	$(1.5\pm0.1)\times10^{-12}$	298	FP-GC	26
CO	$<1.0\times10^{-15}$	298	FP-GC	26
NO	1.0×10^{-11}	298	FP-GC	25
	$(1.6\pm0.1)\times10^{-11}$	298	FP-GC	26
CH_4	$<5\times10^{-14}$	298	FP-A(UV)	22
C_2H_2	4.0×10^{-12}	298	FP-GC	25
	$(7.5\pm1.0)\times10^{-12}$	298	FP-GC	26

$CH_2(\tilde{a}^1A_1)$				
He	$(3.1\pm0.3)\times10^{-12}$	298	IRMPD-LIF	27
Ne	$(4.2\pm0.6)\times10^{-12}$	298	IRMPD-LIF	27
Ar	$(6.0\pm0.5)\times10^{-12}$	298	IRMPD-LIF	27
Kr	$(7.0\pm0.6)\times10^{-12}$	298	IRMPD-LIF	27
Xe	$(1.6\pm0.2)\times10^{-11}$	298	IRMPD-LIF	27
H_2	$(1.30\pm0.10)\times10^{-10}$	298	IRMPD-LIF	27
N_2	$(8.8\pm0.3)\times10^{-12}$	298	IRMPD-LIF	27
O_2	$(3.0\pm0.4)\times10^{-11}$	298	IRMPD-LIF	27
CO	$(5.6\pm0.5)\times10^{-11}$	298	IRMPD-LIF	27
NO	$<4\times10^{-11}$	298	FP-GC	26
CH_4	$(7.3\pm0.6)\times10^{-11}$	298	IRMPD-LIF	27
CH_2CO	$(2.1\pm0.6)\times10^{-10}$	298	LP-GC	28
	3.5×10^{-12}	298	FP-GC	25
	$(3.2\pm1.2)\times10^{-11}$	298	FP-GC	26
$CH_2(\tilde{b}^1B_1)$[e]				
He	$(5.0\pm0.5)\times10^{-11}$	298	IRMPD-LIF	27
Ne	$(6.5\pm0.5)\times10^{-11}$	298	IRMPD-LIF	27
Ar	$(2.0\pm0.3)\times10^{-10}$	298	IRMPD-LIF	27
Kr	$(1.5\pm0.2)\times10^{-10}$	298	IRMPD-LIF	27
Xe	$(2.3\pm0.2)\times10^{-10}$	298	IRMPD-LIF	27
H_2	$(1.9\pm0.3)\times10^{-10}$	298	IRMPD-LIF	27
N_2	$(2.2\pm0.1)\times10^{-10}$	298	IRMPD-LIF	27
O_2	$(1.7\pm0.3)\times10^{-10}$	298	IRMPD-LIF	27
CO	$(3.6\pm0.4)\times10^{-10}$	298	IRMPD-LIF	27
CH_4	$(3.4\pm0.4)\times10^{-10}$	298	IRMPD-LIF	27

C_2H				
H_2	1.5×10^{-13}	297	C_2H_2+H,FP-A-GC	29
O_2	1.0×10^{-12}	297	C_2HO+O,FP-A-GC	30
	4.0×10^{-12}	297	CO+HCO,FP-A-GC	30
	$(2.1\pm0.3)\times10^{-11}$	300	LP or IRMPD-CL	31
CH_4	$(1.2\pm0.2)\times10^{-12}$	297	FP-A-GC	32
C_2H_6	$(6.5\pm0.4)\times10^{-12}$	297	FP-A-GC	32
C_2D_6	$(3.1\pm0.5)\times10^{-12}$	297	C_2HD+C_2D_5,FP-A-GC	32
C_2H_2	$(3.1\pm0.2)\times10^{-11}$	297	C_4H_2+H,FP-A-GC	29
C_2H_3				
O_2	1.0×10^{-11}	296	HCO+CH_2O,LP-PIMS	33
	$(6.6\pm1.3)\times10^{-12}\exp(126\pm50/T)$	297-602	LP-PIMS	33
C_3H_5				
C_3H_5	$k_\infty=1.7\times10^{-11}\exp(132\pm12/T)$	293-571	C_6H_{10},LP-A(UV)	34
O_2	temperature and pressure depend.	382-453	$\rightleftarrows C_3H_5O_2$,LP-PIMS	35
NO	temperature and pressure depend.	296-404	$\rightleftarrows C_3H_5NO$,LP-A(UV)	34
NO_2	$(3.9\pm0.8)\times10^{-11}$	300	IRMPD-PIMS	36
Br_2	$(9.0\pm1.8)\times10^{-12}$	300	IRMPD-PIMS	36
CH_3				
H	$k_\infty=(1.5\pm0.7)\times10^{-10}$	300	CH_4,FP-GC	37
$O(^3P)$	$(1.14\pm0.29)\times10^{-10}$	298	CH_2O+H,DF-PIMS	38
	$(1.38\pm0.46)\times10^{-10}$	298	CH_2O+H,DF-PIMS	39
	$(1.0\pm0.2)\times10^{-10}$	259-341	CH_2O+H,DF-PIMS	40
CH_3	$k_\infty=(4.0\pm0.7)\times10^{-11}$	250-420	C_2H_6, recommended value	41

O_2	$0.8\sim6.1\times10^{-14}$, 0.5∿6.7Torr Ar, N_2	298	CH_3O_2, LP-PIMS	42
	$1\sim5.2\times10^{-14}$, 0.5∿6.5Torr He	298	CH_3O_2, DF-PIMS	38
	$k_\infty=2\times10^{-12}$	200-400	CH_3O_2, Review	43
	$< 5\times10^{-17}$	298	CH_2O+OH, Review	44
Cl_2	$(1.5\pm0.1)\times10^{-12}$	298	CH_3Cl+Cl, LP-FQ(IR)	67
Br_2	$(2.0\pm0.4)\times10^{-11}$	298	CH_3Br+Br, LP-FQ(IR)	67
NO	$k_\infty=(1.2\pm0.1)\times10^{-11}$	298	CH_3NO, FP-GC	45
	$k_\infty=3.2\times10^{-11}$	298	CH_3NO, FP-GC	46
	$k_\infty=1.7\times10^{-11}$	298	CH_3NO, FP-A(UV)	47
	$k_\infty=0.4\times10^{-11}$	298	CH_3NO, FP-A(UV)	48
O_3	$(2.61\pm0.23)\times10^{-12}$	298	LP-PIMS	49
	$(5.4\pm1.5)\times10^{-12}\exp(-216\pm80/T)$	243-384	LP-PIMS	49
NO_2	$(2.5\pm0.5)\times10^{-11}$	295	CH_3O+NO, IRMPD-PIMS	50
SO_2	$(2.9\pm0.4)\times10^{-13}$	298	CH_3SO_2, FP-A(UV)	51

C_2H_5

C_2H_5	$(1.4\pm0.6)\times10^{-11}$	300-850	$D/R^f\approx0.14$, MM-A(UV)	52
	$(2.1\pm0.4)\times10^{-11}$	298	$D/R^f\approx0.14$, FP-A(UV)	53
	$(1.5\pm0.3)\times10^{-11}$	902	$D/R^f\approx0.44$, PY	54
O_2	$1.2\sim3.6\times10^{-12}$, 0.6∿10Torr He	295	$C_2H_5O_2$, DF-PIMS	55
	$k_\infty=4.4\times10^{-12}$	295	$C_2H_5O_2$, DF-PIMS	55
	$3\sim0.8\times10^{-12}$, temperature depend.	294-1002	$C_2H_5O_2$, IRMPD-PIMS	56
	$(2.1\pm0.5)\times10^{-13}$	295	$C_2H_4+HO_2$, DF-PIMS	55
	important above 600K	294-1002	$C_2H_4+HO_2$, IRMPD-PIMS	56
O_3	$(2.53\pm0.58)\times10^{-11}$	298	LP-PIMS	57
NO_2	$(4.5\pm0.9)\times10^{-11}$	298	DF-PIMS	58

$1\text{-}C_3H_7$				
$1\text{-}C_3H_7$	$(1.7\pm0.2)\times10^{-11}$	298	$D/R^f=0.19$, FP-A(UV)	59
O_2	$(5.5\pm0.9)\times10^{-12}$	298	$C_3H_7O_2$, FP-PIMS	60
O_3	$(2.44\pm0.59)\times10^{-11}$	298	LP-PIMS	57
$2\text{-}C_3H_7$				
$2\text{-}C_3H_7$	$(8.0\pm2)(T/300)^{-0.5}\times10^{-12}$	300-800	$D/R^f=0.65$, MM-A(UV)	52
	$(1.3\pm0.3)\times10^{-11}$	298	$D/R^f=0.65$, FP-A(UV)	59
O_2	$(1.41\pm0.24)\times10^{-11}$	298	$C_3H_7O_2$, FP-PIMS	60
O_3	$(4.65\pm1.06)\times10^{-11}$	298	LP-PIMS	57
$1\text{-}C_4H_9$				
O_2	$(7.5\pm1.4)\times10^{-12}$	298	$C_4H_9O_2$, FP-PIMS	61
$2\text{-}C_4H_9$				
O_2	$(1.66\pm0.22)\times10^{-11}$	298	$C_4H_9O_2$, FP-PIMS	61
$t\text{-}C_4H_9$				
$O(^3P)$	$(8.7\pm1.9)\times10^{-10}$	298	DF-PIMS	62
$t\text{-}C_4H_9$	$(4.0\pm0.6)(T/300)^{-1.5}\times10^{-12}$	300-650	$D/R^f=2.8$, MM-A(UV)	52
	7.8×10^{-12}	298	$D/R^f=2.9$, LP-A(IR,L)	63
	1.1×10^{-12}	700	PY-MS	64
O_2	$(2.34\pm0.39)\times10^{-11}$	298	$C_4H_9O_2$, FP-PIMS	61
O_3	$(5.45\pm1.14)\times10^{-11}$	298	LP-PIMS	57
$c\text{-}C_5H_9$				
NO_2	$(3.7\pm0.7)\times10^{-11}$	298	DF-PIMS	58

Benzyl				
O_2	$(0.99\pm0.07)\times10^{-12}$	298	PF-A(UV)	65
	$(1.5\pm0.2)\times10^{-12}$	295-372	LP-LIF	66
NO	$(9.5\pm1.2)\times10^{-12}$	298	PF-A(UV)	65
Cl_2	$(1.12\pm0.11)\times10^{-12}$	295	LP-LIF	66
	$(5.7\pm1.9)\times10^{-12}\exp(-443\pm116/T)$	295-372	LP-LIF	66
o-MB[g]				
O_2	$(1.2\pm0.07)\times10^{-12}$	298	FP-A(UV)	65
NO	$(8.6\pm0.8)\times10^{-12}$	298	FP-A(UV)	65
p-MB[g]				
O_2	$(1.1\pm0.1)\times10^{-12}$	298	FP-A(UV)	65
NO	$(8.9\pm0.9)\times10^{-12}$	298	FP-A(UV)	65

a) 2-M-2B; 2-methyl-2-butene. b) TME; tetramethyl ethylene

c) 2,3-PDE; 2,3-pentadiene. d) 2,4-MPD; 2,4-dimethyl-2,3-pentadiene

e) $CH_2(\tilde{b}^1B_1)\Sigma(0,14,0)$ state. f) D/R; disproportionation/recombination

g) MB; methylbenzyl radical.

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Table 3-3 Rate constants for radicals of group III

Reactant	Rate constant ($cm^3 molecule^{-1} s^{-1}$)	Temp. (K)	Comments	Ref.
$C_2O(\tilde{X}^3\Sigma^-)$				
H	$(3.7\pm1.0)\times10^{-11}$	298	LP-LIF	1
H_2	$(7\pm3)\times10^{-13}$	298	LP-LIF	1
	$<2\times10^{-14}$	298	LP-LIF	2
O_2	$(3.30\pm0.12)\times10^{-13}$	298	LP-LIF	2
NO	$(4.33\pm0.12)\times10^{-11}$	298	LP-LIF	2
CO_2	$<1\times10^{-14}$	298	LP-LIF	2
iso-C_4H_{10}	$(1.12\pm0.05)\times10^{-13}$	298	LP-LIF	2
C_2H_4	$<1\times10^{-14}$	298	LP-LIF	2
C_2H_2	$<1\times10^{-14}$	298	LP-LIF	2
$C_2O(\tilde{A}^3\Pi_i)$				
Ar	$(1.95\pm0.04)\times10^{-12}$	298	LP-LIF-FQ	3
N_2	$(4.00\pm0.07)\times10^{-12}$	298	LP-LIF-FQ	3
O_2	$(5.67\pm0.21)\times10^{-12}$	298	LP-LIF-FQ	3
C_3O_2	$(2.85\pm0.08)\times10^{-11}$	298	LP-LIF-FQ	3
HCCO				
$O(^3P)$	$(2.0\pm0.5)\times10^{-12}$	298	2CO+H, DF-PIMS	4
O_2	$(3.7\pm2.0)\times10^{-14}$	298	DF-PIMS	5
HCO				
H	$(5.5\pm4.0)\times10^{-10}$	298	H_2+CO, LP-A(IC)	6
	$(1.2\pm0.3)\times10^{-10}$	298	FP-A	7
$O(^3P)$	$(2.1\pm0.4)\times10^{-10}$	298	OH+CO, DF-PIMS	8
Br	$(2.8\pm1.2)\times10^{-10}$	298	DF-LIF	29

HCO	$(6\pm4)\times10^{-11}$	298	LP-A(IC)	6
	$(2.3\pm0.5)\times10^{-11}$	298	FP-A	7
O_2	$(5.7\pm1.2)\times10^{-12}$	298	HO_2+CO,DF-PIMS	8
	$(5.6\pm0.9)\times10^{-12}$	298	FP-A	9
	$(4.65\pm0.6)\times10^{-12}$	295	LP-RA	10
	$5.5\times10^{-11}\times T^{-0.4\pm0.3}$	298-503	FP-LA	11
NO	$(8.5\pm1.0)\times10^{-12}$	298	HNO+CO,FP-A	9
	$(1.26\pm0.2)\times10^{-11}$	295	LP-RA	10
	$1.2\times10^{-10}\times T^{-0.4\pm0.3}$	298-503	FP-LA	11
CH_3CO				
CH_3	$k_\infty=1.4\times10^{-10}$	298	FP-A	12
CH_3CO	$k_\infty=5.8\times10^{-11}$	298	FP-A	12
O_2	$k_\infty=(2.0\pm0.4)\times10^{-12}$	298	CH_3CO_3,FP-PIMS	13
NO	$(9.3\pm2.7)\times10^{-13}$	298	FP-PIMS	13
NO_2	$(2.5\pm0.6)\times10^{-11}$	295	CH_3CO_2+NO, IRMPD-PIMS	14
C_6H_5CO				
O_2	$(5.7\pm1.4)\times10^{-12}$	298	FP-PIMS	13
NO	$(9.4\pm3.5)\times10^{-12}$	298	FP-PIMS	13
CH_2OH				
O_2	$(1.4\pm0.4)\times10^{-12}$	298	HO_2+CH_2O,DF-F	15
	$(2^{+2}_{-1})\times10^{-12}$	298	DF-LMR	16
CH_3O				
O_2	1.07×10^{-14}	290	CH_2O+HO_2,LP-LIF	17
	$1.05\times10^{-13}\exp(-1310/T)$	140-355	LP-LIF	17
	1.32×10^{-15}	298	P-GC	18
	$(1.26\pm1.0)\times10^{-13}\exp(-1352\pm340/T)$	296-450	P-GC	18

CO	$<1\times10^{-14}$	298	LP-LIF	19
NO	$(2.08\pm0.12)\times10^{-11}$	298	CH_2O+HNO, LP-LIF	19
	2.6×10^{-11}	383-423	PY-GC	20
NO_2	$(1.68\pm0.05)\times10^{-12}$	298	IRMPD-LIF, RF, MS	21
	7.9×10^{-11}	383-423		20
N_2O	$<2\times10^{-14}$	298	LP-LIF	19
NH_3	$<1\times10^{-13}$	298	LP-LIF	19
iso-C_4H_{10}	$<2\times10^{-13}$	298	LP-LIF	19
1-C_4H_8	$<4\times10^{-13}$	298	LP-LIF	19
CH_3OH	$<1\times10^{-13}$	298	LP-LIF	19
C_2H_5O				
O_2	8×10^{-15}	300	LP-LIF	17
	9.8×10^{-15}	353	LP-LIF	17
C_2H_3O				
O_2	$0.8\sim2.9\times10^{-13}$, pressure depend.	295-473	LP-LIF	22
NO	$2.7\sim18.8\times10^{-12}$, $2.5\sim300$ Torr N_2	295	LP-LIF	22
CH_3O_2				
CH_3O_2	3.7×10^{-13}	298	Review	23
	$(1.40\pm0.20)\times10^{-13}\exp(223\pm41/T)$	248-417	FP-A(UV)	24
NO	7.4×10^{-12}	200-300	CH_3O+NO_2, Review	23
NO_2	$k_0=2.3\times10^{-30}[N_2]$	298	$CH_3O_2NO_2$, Review	23
	$k_0=2.3\times10^{-30}(T/300)^{-4.0}[N_2]$	200-300	$CH_3O_2NO_2$, Review	23
	$k_\infty=8\times10^{-12}$	200-400	$CH_3O_2NO_2$, Review	23

O_3	$<2.0\times10^{-17}$	298	CH_3O+2O_2, Review	23
SO_2	$\leq5\times10^{-17}$	298-423	FP-A(UV)	25
$C_2H_5O_2$				
NO	7.4×10^{-12}	298	$C_2H_5O+NO_2$, Review	23
	$(8.9\pm3.0)\times10^{-12}$	295	DF-PIMS	26
NO_2	$(1.3\pm0.1)\times10^{-12}$	298	FP-A(UV)	27
iso-$C_3H_7O_2$				
NO	$(5.7\pm0.2)\times10^{-12}$	298	FP-A(UV)	28
NO_2	$(3.5\pm0.3)\times10^{-12}$	298	FP-A(UV)	28

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Table 3-4 Rate constants for radicals of group IV

Reactant	Rate constant ($cm^3 molecule^{-1} s^{-1}$)	Temp. (K)	Comments	Ref.
$CCl(\tilde{X}^2\Pi)$				
Ar	$<3x10^{-16}$	298	LP-LIF	1
O_2	$2.9x10^{-12}$	298	LP-LIF	1
NO	$3.7x10^{-11}$	298	LP-LIF	1
SF_6	$2.4x10^{-14}$	298	LP-LIF	1
CH_4	$<3x10^{-16}$	298	LP-LIF	1
CCl_4	$3x10^{-13}$	298	LP-LIF	1
C_3H_8	$<3x10^{-15}$	298	LP-LIF	1
	$<7x10^{-15}$	298	FP-A(UV)	2
iso-C_4H_{10}	$<3x10^{-16}$	298	LP-LIF	1
	$(7.5\pm0.7)x10^{-15}$	298	FP-A(UV)	3
C_2H_4	$2.2x10^{-13}$	298	LP-LIF	1
C_2H_2	$(5.8\pm0.7)x10^{-14}$	298	FP-A(UV)	2
C_2D_2	$(7.0\pm2.2)x10^{-14}$	298	FP-A(UV)	2
CH_3C_2H	$(3.7\pm0.3)x10^{-12}$	298	FP-A(UV)	2
1-C_4H_6	$(6.2\pm0.8)x10^{-12}$	298	FP-A(UV)	2
2-C_4H_6	$(3.0\pm0.5)x10^{-11}$	298	FP-A(UV)	2
1-C_5H_8	$(7.2\pm1.2)x10^{-12}$	298	FP-A(UV)	2
2-C_5H_8	$(4.2\pm0.6)x10^{-11}$	298	FP-A(UV)	2
Me_3C_3H	$(4.0\pm0.5)x10^{-12}$	298	FP-A(UV)	2
$Me_3C_4Me_3$	$(1.3\pm0.1)x10^{-11}$	298	FP-A(UV)	2
$C_6H_5C_2H$	$(7.2\pm1.2)x10^{-12}$	298	FP-A(UV)	2
SiH_4	$(8.0\pm0.8)x10^{-13}$	298	FP-A(UV)	3
SiD_4	$(4.2\pm0.5)x10^{-13}$	298	FP-A(UV)	3

$SiHCl_3$	$<7\times10^{-15}$	298	FP-A(UV)	4
$MeSiH_3$	$(2.8\pm0.3)\times10^{-12}$	298	FP-A(UV)	3
$MeSiHCl_2$	$(4.8\pm0.5)\times10^{-14}$	298	FP-A(UV)	4
Me_2SiH_2	$(4.7\pm0.2)\times10^{-12}$	298	FP-A(UV)	3
Me_2SiHCl	$(6.5\pm0.3)\times10^{-13}$	298	FP-A(UV)	4
Me_3SiH	$(4.7\pm0.3)\times10^{-12}$	298	FP-A(UV)	3
Et_2SiH_2	$(4.8\pm0.5)\times10^{-12}$	298	FP-A(UV)	3
Et_3SiH	$(7.5\pm0.2)\times10^{-12}$	298	FP-A(UV)	3
Si_2H_6	$(1.1\pm0.6)\times10^{-11}$	298	FP-A(UV)	3
Me_6Si_2	$(4.2\pm0.5)\times10^{-14}$	298	FP-A(UV)	3

$CBr(\tilde{X}^2\Pi)$

Ar	$<2\times10^{-16}$	298	LP-A(UV)	5
H_2	$<5\times10^{-15}$	298	FP-A(UV)	6
N_2	$<7\times10^{-15}$	298	FP-A(UV)	6
	$(1.7\pm0.4)\times10^{-15}$	298	LP-A(UV)	5
O_2	$(2.2\pm0.8)\times10^{-12}$	298	FP-A(UV)	6
	$(4.2\pm1.0)\times10^{-12}$	298	LP-A(UV)	5
NO	$(2.2\pm0.3)\times10^{-11}$	298	FP-A(UV)	6
CO_2	$(5.3\pm1.6)\times10^{-13}$	298	LP-A(UV)	5
CH_4	$<5\times10^{-15}$	298	FP-A(UV)	6
iso-C_4H_{10}	$(3.0\pm1.5)\times10^{-14}$	298	FP-A(UV)	6
C_2H_4	$(7.8\pm1.2)\times10^{-13}$	298	FP-A(UV)	6
C_2H_3F	$(3.0\pm0.2)\times10^{-13}$	298	FP-A(UV)	6
$C_2H_2F_2$	$(2.0\pm0.5)\times10^{-13}$	298	FP-A(UV)	6
C_3H_6	$(9.2\pm0.3)\times10^{-12}$	298	FP-A(UV)	6

1-C_4H_8	$(1.5\pm0.2)\times10^{-11}$	298	FP-A(UV)	6
2-C_4H_8	$(1.0\pm0.2)\times10^{-11}$	298	FP-A(UV)	6
T.M.E.[a)]	$(2.0\pm0.2)\times10^{-11}$	298	FP-A(UV)	6
C_2H_2	$(1.4\pm0.1)\times10^{-13}$	298	FP-A(UV)	7
C_2D_2	$(1.2\pm0.3)\times10^{-13}$	298	FP-A(UV)	7
CH_3C_2H	$(8.0\pm1.0)\times10^{-12}$	298	FP-A(UV)	7
1-C_4H_6	$(1.0\pm0.2)\times10^{-11}$	298	FP-A(UV)	7
2-C_4H_6	$(4.0\pm0.8)\times10^{-11}$	298	FP-A(UV)	7
2-C_4F_6	$(3.3\pm0.3)\times10^{-14}$	298	FP-A(UV)	7
1-C_5H_8	$(6.0\pm1.3)\times10^{-12}$	298	FP-A(UV)	7
2-C_5H_8	$(3.3\pm0.5)\times10^{-11}$	298	FP-A(UV)	7
$Me_3C_4Me_3$	$(1.6\pm0.3)\times10^{-11}$	298	FP-A(UV)	7
$CHF(\tilde{X}^1A')$				
$O(^3P)$	$(1.5\pm0.2)\times10^{-10}$	295	$CO(A^1\Pi)$,IRMPD-LIF	8
$N(^4S)$	$(2.5\pm0.5)\times10^{-11}$	295	$CN(B^2\Sigma^+)$,IRMPD-LIF	8
O_2	$<5\times10^{-16}$	295	IRMPD-LIF	9
NO	$(7.0\pm0.4)\times10^{-12}$	295	NCO+HF,IRMPD-LIF	9
$CF_2(\tilde{A}^1B_1)$[b]				
O_2	$(2.7\pm0.5)\times10^{-11}$	298	LP-FQ	10
CO	$(3.8\pm0.5)\times10^{-11}$	298	LP-FQ	10
CH_4	$(1.0\pm0.5)\times10^{-11}$	298	LP-FQ	10
C_2H_6	$(6.7\pm1.3)\times10^{-11}$	298	LP-FQ	10
C_3H_8	$(1.1\pm0.3)\times10^{-10}$	298	LP-FQ	10
C_2H_4	$(4.0\pm0.3)\times10^{-10}$	298	LP-FQ	10
C_2F_4	$(7.8\pm0.5)\times10^{-11}$	298	LP-FQ	10
C_3H_6	$(3.8\pm0.5)\times10^{-10}$	298	LP-FQ	10

cis-C_4H_8	$(6.2\pm0.8)\times10^{-10}$	298	LP-FQ	10
C_6F_6	$(4.0\pm0.3)\times10^{-10}$	298	LP-FQ	10
$(CH_3)_2CO$	$(6.7\pm0.8)\times10^{-10}$	298	LP-FQ	10
$CF_2(^3B_1)$				
Xe	$<7.0\times10^{-14}$	298	DF-FQ	11
O_2	4.1×10^{-12}	298	DF-FQ	11
NO	$>4.8\times10^{-11}$	298	DF-FQ	11
C_3H_8	6.7×10^{-13}	298	DF-FQ	11
iso-C_4H_{10}	1.8×10^{-12}	298	DF-FQ	11
C_2H_4	9.0×10^{-12}	298	DF-FQ	11
C_2F_4	3.9×10^{-13}	298	DF-FQ	11
C_3H_6	2.2×10^{-11}	298	DF-FQ	11
$CFCl(\tilde{X}^1A')$				
Ar	$<3\times10^{-16}$	298	LP-LIF	1
$O(^3P)$	$(2.9\pm1.2)\times10^{-12}$	298	DF-LIF	12
CFCl	1.3×10^{-13}	298	DF-LIF	12
N_2	$<10^{-16}$	300	IRMPD-LIF	13
O_2	$<3\times10^{-16}$	298	LP-LIF	1
	$<2.5\times10^{-16}$	333	DF-LIF	12
	$<10^{-16}$	300	IRMPD-LIF	13
F_2	6.7×10^{-15}	298	LP-LIF	1
Cl_2	$(1.27\pm0.06)\times10^{-13}$	300	DF-LIF	12
	$(7.9\pm0.3)\times10^{-13}\exp(-547\pm10/T)$	300-358	DF-LIF	12
Br_2	$(3.83\pm0.24)\times10^{-14}$	296	DF-LIF	12
	$(9.6\pm2.4)\times10^{-13}\exp(-943\pm82/T)$	296-358	DF-LIF	12

NO	1×10^{-14}	298	LP-LIF	1
	$(1.38\pm0.10)\times10^{-15}$	333	DF-LIF	12
	$(1.6\pm0.2)\times10^{-14}$	300	IRMPD-LIF	13
CO	1.5×10^{-15}	298	LP-LIF	1
NO_2	$(8.7\pm0.7)\times10^{-15}$	300	IRMPD-LIF	13
	$(2.85\pm0.22)\times10^{-15}$	333	DF-LIF	12
N_2O	$<10^{-16}$	300	IRMPD-LIF	13
C_3H_8	$<1.2\times10^{-15}$	298	LP-LIF	1
C_2H_4	$<3\times10^{-15}$	298	LP-LIF	1
CF_2CFCl	$<10^{-15}$	298	DF-LIF	12
$CFBr(\tilde{X}^1A')$				
O_2	$<2\times10^{-16}$	298-353	DF-LIF	14
CL_2	$(1.55\pm0.21)\times10^{-13}$	302	DF-LIF	15
	$(1.9\pm0.6)\times10^{-12}\exp(-762\pm92/T)$	302-361	DF-LIF	14
Br_2	$(2.24\pm0.11)\times10^{-13}$	298	DF-LIF	14
	$(1.4\pm0.3)\times10^{-12}\exp(-553\pm62/T)$	298-355	DF-LIF	15
NO	$<10^{-14}$	298	DF-LIF	15
CF_2CFBr	$<10^{-15}$	298	DF-LIF	14
$CCl_2(\tilde{X}^1A')$				
Ar	$<3\times10^{-16}$	298	LP-LIF	1
O_2	$<3\times10^{-15}$	298	LP-LIF	1
F_2	3×10^{-13}	298	LP-LIF	1
CO	5×10^{-14}	298	LP-LIF	1
NO	3×10^{-13}	298	LP-LIF	1
C_3H_8	3×10^{-15}	298	LP-LIF	1
C_2H_4	$<3\times10^{-15}$	298	LP-LIF	1

CF_3				
$O(^3P)$	$(3.1\pm0.8)\times10^{-11}$	295	CF_2O+F, DF-MS	16
O_2	$2.2-12.4\times10^{-13}$, 0.5-9Torr He	295	CF_3O_2/CF_2O+FO, DF-MS	16
Br_2	$(1.3\pm0.2)\times10^{-12}$	298	CF_3Br+Br, IRMPD-MS	17
O_3	$(9.3\pm0.1)\times10^{-13}$	298	CF_3O+O_2, IRMPD-MS	17
NO_2	$(2.7\pm0.5)\times10^{-12}$	298	CF_3O+NO, IRMPD-MS	17
H_2S	$1.2\times10^{-13}\exp(-2110\pm80/T)$	314-434	CF_3H+HS, P-GC	18
ClNO	$(5.8\pm0.8)\times10^{-13}$	298	CF_3Cl+NO, IRMPD-MS	17
CF_2Cl				
NO_2	$(9.6\pm1.9)\times10^{-12}$	295	$CF_2ClO+NO$, IRMPD-PIMS	19
$CFCl_2$				
O_2	$k_\infty=(6.0\pm1.0)\times10^{-12}$	298	$CFCl_2O_2$, LP-MS	20
CCl_3				
$O(^3P)$	$(4.2\pm0.6)\times10^{-11}$	295	CCl_2O+Cl, DF-MS	21
O_2	$1.51-7.88\times10^{-14}$, 1-9 Torr He	295	CCl_3O_2, DF-MS	21
$CFCl_2O_2$				
NO	$(1.6\pm0.2)\times10^{-11}$	298	$CFCl_2O+NO$, LP-MS	22
NO_2	$(3.5\pm0.5)\times10^{-29}[O_2]$	298	$CFCl_2O_2NO_2$, LP-MS	22
	$k_\infty=(6.0\pm1.0)\times10^{-12}$	298	$CFCl_2O_2NO_2$, LP-MS	22
CCl_3O_2				
NO	$(1.86\pm2.8)\times10^{-11}$	295	CCl_3O+NO, DF-MS	21

[a] T.M.E.: tetramethyl ethylene. [b] $CF_2(\tilde{A}^1B_1,0,6,0)$ removal rate.

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Table 3-5 Rate constants for radicals of group V

Reactant	Rate constant ($cm^3 molecule^{-1} s^{-1}$)	Temp. (K)	Comments	Ref.
$NH(X^3\Sigma^-)$				
NH	$4.15x10^{-11}$	1200-1350	ST-RA	1
N_2	$<3x10^{-19}$	298	FP-RF	2
NO	$(4.7\pm1.2)x10^{-11}$	300	FP-DF	3
O_2	$(8.5\pm0.9)x10^{-15}$	300	FP-RF	4
NH_3	$<8x10^{-17}$	298	FP-RF	2
$NH(a^1\Delta)$				
O_2	$1.55x10^{-11}$	300	$NH(^3\Sigma,v)+O_2(^1\Delta)$ LP-RF	5
HCl	$(7.9\pm0.8)x10^{-11}$	300	NH_2+Cl	6
HN_3	$9.3x10^{-11}$			7,8
	$1.8x10^{-10}$			9
CH_4	$(1.2\pm0.1)x10^{-11}$	300	LP-RF	6
C_2H_6	$(1.2\pm0.3)x10^{-11}$	300	P-GC	10
C_3H_8	$(4.2\pm0.8)x10^{-11}$	300	P-GC	11
cyclo-C_6H_{12}	$(6.7\pm0.7)x10^{-11}$	300	LP-RF	6
C_2H_4	$(3.8\pm0.4)x10^{-11}$	300	LP-RF	6
$NH(b^1\Sigma^+)$				
He	$(7.04\pm0.15)x10^{-17}$	293	Quenching P-FQ	12
Ar	$(1.27\pm0.04)x10^{-16}$	293	Quenching P-FQ	12
Xe	$(2.8\pm0.6)x10^{-15}$	300	Quenching P-FQ	13
O	$(1.78\pm0.09)x10^{-11}$	293	Quenching P-FQ	12
N	$(3.38\pm0.07)x10^{-11}$	293	P-FQ	12
H_2	$(1.00\pm0.08)x10^{-12}$	293	P-FQ	12

N_2	$(4.48\pm0.20)\times10^{-16}$	293	P-FQ	14
O_2	$(2.44\pm0.84)\times10^{-15}$	293	P-FQ	14 a
NO	$(4.6\pm0.6)\times10^{-12}$	293	P-FQ	13
NH_3	$(3.90\pm0.19)\times10^{-13}$	293	P-FQ	14 a
$1\text{-}C_4H_8$	$(6.3\pm1.4)\times10^{-13}$	203	P-FQ	13
$1,3\text{-}C_4H_6$	$\sim2\times10^{-10}$	293	P-FQ	13
C_6H_6	$(3.0\pm1.3)\times10^{-13}$	293	P-FQ	13
CH_3OH	$(1.09\pm0.09)\times10^{-11}$	293	P-FQ	13
CH_3NH_2	$(1.0\pm0.2)\times10^{-11}$	923	P-FQ	13
$NH_2(\tilde{X}^2B_1)$				
$N(^4S)$	$(1.21\pm0.14)\times10^{-10}$	297	2NH, LP-LIF	14b
NH_2	$(1.29\pm0.30)\times10^{-11}$	298	N_2H_4, LP-RA(L)	15
HO_2	$(3.4\pm0.4)\times10^{-11}$	298	Review	16
H_2	$2.1\times10^{-12}\exp(-4280\pm200/T)$	300-520	NH_3+H, FP-RA(L)	17
O_2	$<3\times10^{-18}$	298	Review	16
	$(3.6\pm1.4)\times10^{-33}(T/295)^{-(2.0\pm0.5)}$[He]	295-353	NH_2O_2, DF-LIF	18
	$<1.5\times10^{-36}[N_2]$	298	LP-RA(L)	15
NO	$(1.7\pm0.3)\times10^{-11}$	298	Review	16
	$1.7\times10^{-11}(T/298)^{-(1.6\pm0.5)}$	210-500	Review	16
	$(4.38\pm0.70)\times10^{-5}T^{-(2.30\pm0.02)}\exp(-684\pm60/T)$	294-1215	N_2+H_2O, DF-LIF, MS	19
NO_2	$(1.7\pm0.5)\times10^{-11}$	298	Review	16
	$1.7\times10^{-11}(T/298)^{-(2.2\pm1.5)}$	250-500	Review	16
	$(2.11\pm0.18)\times10^{-11}$	294	LP-LIF	14b

O_3	$(1.2\pm0.5)x10^{-13}$	298	Review	16
	$3.4x10^{-12}exp(-1000\pm500/T)$	250-380	Review	16
	$(1.57\pm0.51)x10^{-11}exp(-1151\pm123/T)$	272-348	LP-RA(L)	15
C_2H_6	$6.2x10^{-13}exp(-3600\pm140/T)$	300-520	FP-RA(L)	17
C_3H_8	$7.5x10^{-13}exp(-3100\pm130/T)$	300-520	FP-RA(L)	17
n-C_4H_{10}	$1.2x10^{-12}exp(-3070\pm130/T)$	300-520	FP-RA(L)	17
iso-C_4H_{10}	$3.8x10^{-13}exp(-2470\pm110/T)$	300-520	FP-RA(L)	17
	$(1.03\pm0.15)x10^{-16}$	300	FP-RA(L)	20
	$4.0x10^{-13}exp(-2500\pm100/T)$	300-500	FP-RA(L)	20
C_2H_4	$(2.75\pm0.42)x10^{-16}$	300	FP-RA(L)	20
	$2.0x10^{-13}exp(-1990\pm100/T)$	300-500	FP-RA(L)	20
	$(2.2\pm0.5)x10^{-15}$	295-505	DF-LIF	21
C_3H_6	$(3.58\pm0.58)x10^{-16}$	300	FP-RA(L)	20
	$4.7x10^{-13}exp(-2160\pm100/T)$	300-500	FP-RA(L)	20
	$\leq1x10^{-15}$	298	DF-LIF	21
1-C_4H_8	$(5.00\pm0.75)x10^{-16}$	300	FP-RA(L)	20
	$4.7x10^{-13}exp(-2063\pm100/T)$	300-500	FP-RA(L)	20
trans-C_4H_8	$(4.92\pm0.75)x10^{-16}$	300	FP-RA(L)	20
	$5.8x10^{-13}exp(-2140\pm100/T)$	300-500	FP-RA(L)	20
cis-C_4H_8	$(4.25\pm0.67)x10^{-16}$	300	FP-RA(L)	20
	$5.5x10^{-13}exp(-2160\pm100/T)$	300-500	FP-RA(L)	20
iso-C_4H_8	$(4.25\pm0.67)x10^{-16}$	300	FP-RA(L)	20
	$7.7x10^{-13}exp(-2260\pm100/T)$	300-500	FP-RA(L)	20
allene	$\leq8x10^{-16}$	298	DF-LIF	21
1,3-butadiene	$1.1x10^{-14}$	300	DF-LIF	22
	$6.3x10^{-13}exp(-1140/T)$	230-360	DF-LIF	22
C_2H_2	$2.4x10^{-8}T^{-2.7}$	210-505	DF-LIF	21

$NH_2(\tilde{A}^2A_1)$				
He	$(1.45\pm0.29)\times10^{-10}$	300	Quenching, DF-FQ	23
Ar	$(1.52\pm0.27)\times10^{-10}$	300	Quenching, DF-FQ	23
H_2	$(4.57\pm0.87)\times10^{-10}$	300	Quenching, DF-FQ	23
N_2	$(4.09\pm0.25)\times10^{-10}$	300	Quenching, DF-FQ	23
CO	$(4.66\pm0.70)\times10^{-10}$	300	Quenching, DF-FQ	23
NH_3	$(1.0\pm0.1)\times10^{-9}$	300	Quenching, DF-FQ	23
	$(6.1\pm0.2)\times10^{-10}$	300	LP-FQ	24
CH_4	$(3.06\pm0.70)\times10^{-10}$	300	LP-FQ	23
N_3				
N	$(1.6\pm1.1)\times10^{-11}$	298	$N_2(B)+N_2$, DF-CL	25
$O(^3P)$	$(10\pm4)\times10^{-12}$	298	$NO(A^2\Sigma^+)+N_2$, PY-CL	26
F	$\sim2\times10^{-12}$	298	$NF+N_2$, DF-CL	27
Cl	$(1.1\pm0.4)\times10^{-11}$	298	$NCl+N_2$, DF-MS	28
NO	$(1.19\pm0.31)\times10^{-12}$	295	N_2O+N_2, DF-MS	29
N_3	1.4×10^{-12}	298	$N_2(B)+2N_2$, DF-CL	25
	$6\pm2\times10^{-11}$	298	$3N_2$, DF-MS	28
HNO				
H	$>1.6\times10^{-12}$	298	H_2+NO, DF-PIMS	30
HNO	$(5.35\pm1.8)\times10^{-15}$	298	N_2O+H_2O, FP-A	31
NO_3				
O	$(1.0\pm0.4)\times10^{-11}$	298	O_2+NO_2, P-A(IR, vis,UV)	32
Cl	$(7.6\pm1.1)\times10^{-11}$	296	$ClO+NO_2$, P-A	33
ClO	$(4.0\pm1.7)\times10^{-13}$	296	$ClOO+NO_2$, P-A	33

NO_3	$(8.5\pm2.8)\times10^{-13}\exp(-2450\pm100/T)$	298-329	$2NO_2+O_2$, P-A	32
NO	$(2\pm1)\times10^{-11}$	298	$2NO_2$, LP-A	34
	$(1.9\pm0.4)\times10^{-11}$	297	$2NO_2$, P-A	32
NO_2	4.5×10^{-30}[Ne]	298	N_2O_5, FP-A	35
	$k_\infty=1.65\times10^{-12}$	298	N_2O_5, FP-A	35
	$k_\infty=(2.2\pm0.5)\times10^{-12}$	298	N_2O_5, LP-A	34
$n-C_4H_{10}$	$(2.0\pm1.0)\times10^{-17}$	296	FTIR	36
$i-C_4H_{10}$	$(2.9\pm1.4)\times10^{-17}$	296	FTIR	36
$n-C_8H_{18}$	$(5.5\pm2.5)\times10^{-17}$	296	FTIR	36
C_2H_4	$(6.1\pm2.6)\times10^{-17}$	298	FTIR	37
	$(1.09\pm0.12)\times10^{-15}$	298	A(IR)	38
C_3H_6	$(4.2\pm0.9)\times10^{-15}$	298	FTIR	37
	$(6.2\pm0.4)\times10^{-15}$	298	A(IR)	38
	$(3.5\pm0.9)\times10^{-15}$	298	A(IR)	39
cis-2-C_4H_8	$(1.89\pm0.22)\times10^{-13}$	298	FTIR	37
	$(2.1\pm0.23)\times10^{-13}$	298	A(IR)	38
TME[a)]	$(3.1\pm1.0)\times10^{-11}$	298	FTIR	37
	$(4.3\pm0.6)\times10^{-11}$	298	A(IR)	38
$1,3-C_4H_6$	$(5.34\pm0.62)\times10^{-14}$	295	FTIR	40
C_6H_6	$<2.3\times10^{-17}$	298	A(IR)	38
	$<3.5\times10^{-17}$	298	FTIR	41
Toluene	$(1.8\pm1.0)\times10^{-17}$	298	FTIR	41
	$<3.5\times10^{-17}$	298	A(IR)	38
o-xylene	$(1.1\pm0.5)\times10^{-16}$	298	FTIR	41
m-xylene	$(7.1\pm3.4)\times10^{-17}$	298	FTIR	41
o-cresol	$(1.20\pm0.34)\times10^{-11}$	298	FTIR	41
m-cresol	$(9.2\pm2.4)\times10^{-12}$	298	FTIR	41
p-cresol	$(1.27\pm0.36)\times10^{-11}$	298	FTIR	41
α-pinene	$(3.4\pm0.8)\times10^{-12}$	295	FTIR	40
CH_3CHO	$(1.4\pm0.35)\times10^{-15}$	298	A(IR)	39

phenol	$(2.1\pm0.5)\times10^{-12}$	298	FTIR	41
benzaldehyde	$(1.13\pm0.25)\times10^{-15}$	298	FTIR	41
CH_3SCH_3	$(5.4\pm0.7)\times10^{-13}$	296	FTIR	42
$CN(X^2\Sigma, v''=0)$				
$O(^3P)$	$(1.8\pm0.5)\times10^{-11}$	295	$CO(v)+N(^4S,^2D)$, FP, DF-A	43
	2.1×10^{-11}	298	FP-A	44
N	$(1.00\pm0.13)\times10^{-10}$	300	$C+N_2$, LP-LIF	45
H_2	$(1.6\pm0.3)\times10^{-14}$	300	HCN+H, LP-LIF	46
	$(1.4\pm0.5)\times10^{-14}$	300	FP-A	47
	$(1.0\pm0.3)\times10^{-10}\exp(-2660\pm300/T)$	275-398	FP-A	48
N_2	no reaction	300	LP-LIF	46
O_2	$(2.0\pm0.1)\times10^{-11}$	300	NCO+O, LP-LIF	46
	1.35×10^{-11}	300	LP-LIF	45
	$(1.12\pm0.03)\times10^{-11}$	303	DF-A	49
	1.1×10^{-11}	298	FP-A	44
	$(5.3\pm1.7)\times10^{-11}\exp(-505\pm170/T)$	275-398	FP-A	48
CO	no reaction	300	LP-LIF	46
NO	$(1.2\pm0.6)\times10^{-13}$	298	N_2+CO, FP-LIF	50
	$(7.7\pm1.4)\times10^{-31}[Ar]$	298	NOCN, FP-LIF	50
HCN	$(1.8\pm0.6)\times10^{-14}$	300	C_2N_2+H, LP-LIF	46
CO_2	$(2.3\pm0.4)\times10^{-14}$	300	NCO+CO, LP-LIF	46
NH_3	2×10^{-14}	300	DF-A	51
C_2N_2	1.1×10^{-12}	303	DF-A	49
CH_4	$(5.6\pm0.3)\times10^{-13}$	300	HCN+CH_3, LP-LIF	46
	$(5\pm3)\times10^{-13}$	293	FP-A	47
	$(7.4\pm0.2)\times10^{-13}$	300	DF-A	49

C_2H_6	7.4×10^{-13}	300	DF-A	53
C_2H_4	1.9×10^{-10}	300	DF-A	53
C_3H_6	2.7×10^{-10}	300	DF-A	53
1,3-C_4H_6	4.3×10^{-10}	300	DF-A	53
C_6H_6	2.8×10^{-10}	300	DF-A	53
$CN(X^2\Sigma, v''=1)$				
$O(^3P)$	2.1×10^{-11}	298	CO+N, FP-A	44
H_2	$(3.0\pm0.4)\times10^{-14}$	300	HCN+H, LP-LIF	46
	$(1.7\pm0.5)\times10^{-13}$	297	FP-A	47
N_2	$(1.5\pm0.6)\times10^{-15}$	300	LP-LIF	46
O_2	$(2.4\pm0.1)\times10^{-11}$	300	NCO+O, LP-LIF	46
	1.25×10^{-11}	298	LP-LIF	45
	$(1.30\pm0.03)\times10^{-11}$	303	FP-A	49
	9×10^{-12}	298	FP-A	44
CO	$(1.3\pm0.4)\times10^{-12}$	300	$CN(v''=0)+CO(v''=1)$, LP-LIF	46
NO	$(2.6\pm0.5)\times10^{-13}$	298	N_2+CO, $CN(v''=0)+NO(v''=1)$, FP-LIF	50
	$(3.0\pm1.1)\times10^{-31}$[Ar]	298	NOCN, FP-LIF	50
HCN	$(4.0\pm0.5)\times10^{-13}$	300	$HCN(100)+CN(v''=0)$, LP-LIF	46
CO_2	$(4.0\pm0.4)\times10^{-14}$	300	$CN(v''=0)+CO_2(001)$, LP-LIF	46
C_2N_2	$(1.1\pm0.1)\times10^{-13}$	300	LP-LIF	46
CH_4	$(8.4\pm0.3)\times10^{-13}$	300	LP-LIF	46
	$(1.12\pm0.3)\times10^{-12}$	293		47

$CN(X^2\Sigma, v''=7)$				
$O(^3P)$	$1.1x10^{-10}$	298	FP-A	44
O_2	$2.6x10^{-12}$	298	FP-A	44
$NF(X^3\Sigma^-)$				
H	$(2.5\pm0.5)x10^{-13}$	298	HF+N, DF-RA	54
NF	$(7.0\pm3.5)x10^{-11}$	298	N_2+2F, DF-RA	54
$NF(b^1\Sigma^+)$				
Ar	$<1x10^{-17}$	298	DF-FQ	55
NF_3	$(1.8\pm0.7)x10^{-12}$	298	DF-FQ	55
NF_2				
H	$(1.5\pm0.2)x10^{-11}$	298	HF+NF, DF-RA	54
	$3.8x10^{-12}$	298	HF($v\geq1$)+NF, DF-CL	56
N	$(3.0\pm1.2)x10^{-12}$	298	NF+NF, DF-RA	54
	$(5.7\pm0.8)x10^{-11}$	298	NF+NF, DF-EPR	57
O	$(1.8\pm0.9)x10^{-12}$	298	NF+FO, DF-RA	54
	$(2.8\pm0.4)x10^{-11}$	298	NF+FO, DF-EPR	57
$NCl(X^3\Sigma^-)$				
$O(^3P)$	$(1.2\pm0.6)x10^{-10}$	295	NO+Cl, DF-MS	58
NCl	$(7\pm3)x10^{-12}$	298	N_2+Cl_2, DF-MS	28
	$(8.1\pm1.8)x10^{-12}$	295	N_2+2Cl, DF-MS	58
Cl_2	$(1.0\pm0.2)x10^{-12}$	300	NCl_2+Cl, DF-MS	59

$NCl(b^1\Sigma^+)$				
H_2	$(2.1\pm0.1)\times10^{-13}$	300	LP-FQ	60
F_2	$(2.0\pm0.2)\times10^{-13}$	300	LP-FQ	60
Cl_2	$(1.5\pm0.7)\times10^{-14}$	300	LP-FQ	60
HF	$(1.7\pm0.1)\times10^{-12}$	300	LP-FQ	60
HCl	$(9.3\pm0.9)\times10^{-13}$	300	LP-FQ	60
CO_2	$(4.8\pm0.2)\times10^{-14}$	300	LP-FQ	60
ClN_3	$(1.35\pm0.04)\times10^{-12}$	300	LP-FQ	60
NCl_2				
NCl_2	$(5.5\pm0.4)\times10^{-11}$	298	FP-A	61

a) TME: 2,3-dimethyl-2-butene (Tetramethylethylene)

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Table 3-6 Rate constants for radicals of group VI

Reactant	Rate constant ($cm^3 molecule^{-1} s^{-1}$)	Temp. (K)	Comments	Ref.
OH				
$O(^3P)$	$(2.3\pm1.0)x10^{-11}exp(+110\pm100/T)$	220-500	O_2+H, Review	1
N	$(3.8\pm1.5)x10^{-11}exp(+85\pm100/T)$	250-500	NO+H, Review	1
OH	$(1.8\pm0.7)x10^{-12}$	298	H_2O+O, Review	1
	$(6.9\pm6.0)x10^{-31}(T/300)^{-0.8\pm1.0}[N_2]$	200-300	H_2O_2, Review	1
HO_2	$(1.1\pm0.6)x10^{-10}$	298	H_2O+O_2, Review	1
NO	$(7.4\pm2.0)x10^{-31}(T/300)^{-2.4\pm0.5}[N_2]$	220-440	HONO, Review	1
H_2	$(7.7\pm2.0)x10^{-12}exp(-2100\pm200/T)$	200-450	H_2O+H, Review	1
CO	$(1.5\pm0.2)x10^{-13}$	200-300	$H+CO_2$, Review	1
HCl	$(2.8\pm0.4)x10^{-12}exp(-425\pm100/T)$	210-460	H_2O+Cl, Review	1
HBr	$(8.0\pm8.0)x10^{-12}$	249-416	H_2O+Br, Review	1
O_3	$(1.9\pm0.8)x10^{-12}exp(-1000\pm300/T)$	220-450	HO_2+O_2, Review	1
NO_2	$(2.6\pm0.6)x10^{-30}(T/300)^{-2.9\pm0.5}[N_2]$	200-300	$HONO_2$, Review	1
SO_2	$(3.0\pm3.0)x10^{-31}(T/300)^{-2.9\pm1.0}[N_2]$	200-400	$HOSO_2$, Review	1
H_2S	$(6.3\pm1.5)x10^{-12}exp(-80\pm80/T)$	200-300	H_2O+HS, Review	1
CS_2	$\leq 7.0x10^{-15}$	298	Review	1
OCS	$(1.3\pm1.0)x10^{-12}exp(-2300\pm250/T)$	200-520	Review	1
H_2O_2	$(2.9\pm0.7)x10^{-12}exp(-160\pm100/T)$	240-460	H_2O+HO_2, Review	1
NH_3	$(3.3\pm1.3)x10^{-12}exp(-900\pm200/T)$	230-450	H_2O+NH_2, Review	1
CH_4	$(2.4\pm0.6)x10^{-12}exp(-1710\pm200/T)$	200-300	H_2O+CH_3, Review	1
CH_3Cl	$(1.9\pm0.5)x10^{-12}exp(-1120\pm200/T)$	247-350	H_2O+CH_2Cl, Review	1
CH_3Br	$(7.6\pm2.0)x10^{-13}exp(-890\pm200/T)$	244-350	H_2O+CH_2Br, Review	1

CH_2FCl	$(2.6\pm0.6)x10^{-12}exp(-1210\pm100/T)$	245-350	$H_2O+CHCFCl$, Review	1
CHF_2Cl	$(1.1\pm0.3)x10^{-12}exp(-1620\pm100/T)$	250-360	H_2O+CF_2Cl, Review	1
C_2H_6	$(1.9\pm0.2)x10^{-11}exp(-1230\pm50/T)$	297-493	$H_2O+C_2H_5$, Review	2
C_3H_8	$(1.2\pm0.2)x10^{-11}exp(-680\pm40/T)$	296-497	$H_2O+C_3H_7$, Review	2
$i\text{-}C_4H_{10}$	$(8.7\pm2.0)x10^{-12}exp(-390\pm60/T)$	297-498	$H_2O+C_4H_9$, Review	2
C_2H_4	$(2.2\pm1.3)x10^{-12}exp(+400\pm200/T)$	200-300	Review	1
	$(9.5^{+9.0}_{-5.0})x10^{-29}exp(T/300)^{-3.1\pm2.0}[N_2]$	200-300		
	$k_\infty=(9^{+9}_{-4})x10^{-12}$			
C_3H_6	$8x10^{-27\pm1}(T/300)^{-3.5\pm1.0}[N_2]$	298-424	Review	
	$k_\infty=(3.0\pm2.0)x10^{-11}$			
cis-2-butene	$(1.0\pm0.1)x10^{-11}exp(+480\pm150/T)$	298-425	Review High-pressure	2
trans-2-butene	$(1.1\pm0.1)x10^{-11}exp(+550/150/T)$	298-425	Review High-pressure	2
C_2H_2	$2x10^{-29\pm0.5}(T/300)^{-1.3\pm2}[N_2]$	200-300	Review	1
	$k_\infty=(6.5^{+6.0}_{-3.0})x10^{-12}exp(-650\pm350/T)$	200-300		
$CH_3\text{-}C{\equiv}CH$	$(1.9\pm0.2)x10^{-12}exp(-310\pm200/T)$	298-422	Review High-pressure	2
H_2CO	$(1.1\pm0.3)x10^{-11}$	200-425	H_2O+HCO, $H_2O+H+CO$	1
CH_3OH	$(1.0\pm0.3)x10^{-12}$	298	H_2O+CH_2OH, H_2O+CH_3O	1
CH_3CHO	$(6.9\pm1.5)x10^{-12}exp(+260\pm300/T)$	298-450	H_2O+CH_3CO, Review	1
CH_3OCH_3	$(1.3\pm0.2)x10^{-11}exp(+390\pm150/T)$	299-424	Review	2
CH_3SH	$(8.9\pm1.0)x10^{-12}exp(+400\pm150/T)$	300-423	Review	2
CH_3SCH_3	$(7.8\pm5.0)x10^{-12}$		Review	1
CH_3NH_2	$(1.0\pm0.1)x10^{-11}exp(+230\pm150/T)$	299-426	Review	2
$(CH_3)_2NH$	$(2.9\pm0.3)x10^{-11}exp(+250\pm150/T)$	299-425	Review	2
$(CH_3)_3N$	$(2.6\pm0.3)x10^{-11}exp(+250\pm150/T)$	299-425	Review	2
CH_3ONO	$(1.6\pm0.2)x10^{-12}$	292	Review	2
CH_3NO_2	$(1.1\pm0.1)x10^{-12}$	292	Review	2
Benzene	$(1.2\pm0.3)x10^{-12}$	298	Review	2
Toluene	$(6.0\pm0.5)x10^{-12}$	298	Review	2
p-Xylene	$(1.2\pm0.3)x10^{-11}$	298	Review	2

HO_2

H	1.4×10^{-11}	298	H_2+O_2, Review	3
	3.2×10^{-11}	298	2HO, Review	3
	$<9.4\times10^{-13}$	298	H_2O+O, Review	3
	$(7.4\pm1.2)\times10^{-11}$	296	over all, DF-LIF,RF	4
	$(5.0\pm1.3)\times10^{-11}$	298	over all, DF-LMR	5
N	$(2.2\pm0.5)\times10^{-11}$	300	DF-LMR, RF, RA	6
$O(^3P)$	$(2.9\pm1.0)\times10^{-11}\exp(+200\pm200/T)$	298	$HO+O_2$, Review	1
	$(5.2\pm0.8)\times10^{-11}$	300	DF-LMR, RF, RA	6
	$(6.2\pm1.1)\times10^{-11}$	298	LF-RF	7
	$(5.4\pm0.9)\times10^{-11}$	296	DF-LIF, RF	4
	$(6.1\pm0.4)\times10^{-11}$	299	DF-RF	8
Cl	$(1.8\pm1.0)\times10^{-11}\exp(+170\pm250/T)$	274-338	$HCl+O_2$, Review	1
	$(4.2\pm0.7)\times10^{-11}$	250-414	over all, DF-LMR	9
	$(1.8\pm0.5)\times10^{-11}\exp(170\pm80/T)$	250-414	$HCl+O_2$, DF-LMR	9
	$(4.1\pm0.8)\times10^{-11}\exp(-450\pm60/T)$	250-414	OH+ClO, DF-LMR	9
Br	$(7.6\pm0.9)\times10^{-13}$	298	$HBr+O_2$, DF-LIF, MS	10
OH	$(1.1\pm0.6)\times10^{-10}$	298	H_2O+O_2, Review	1
	$(1.7\pm0.5)\times10^{-11}\exp(416\pm86/T)$	298	DF-RF, LIF	11
ClO	5.0×10^{-12}	298	$HOCl+O_2$, Review	1
	$4.6\times10^{-13}\exp(710/T)$	235-298	$HOCl+O_2$, Review	1
	$<2.0\times10^{-14}$	298	HOOClO, Review	1
HO_2	2.5×10^{-12}	298	$H_2O_2+O_2$, Review	1
	$4.5\times10^{-14}\exp(1200/T)$	275-400	Review	1
	$(1.5\pm0.3)\times10^{-12}$	295	1-7Torr He, DF-LMR	12
	temperature and pressure depend.	240-417	100-1000Torr N_2,FP-A	13
	$2.4\times10^{-13}\exp(560/T)$	298-358	7-20Torr N_2, FP-A(IR)	14
	$(4.14\pm1.15)\times10^{-13}\exp(630\pm115/T)$	298-510	700Torr N_2, FP-A(UV)	15
	$(1.65\pm0.3)\times10^{-12}$	298	2-25Torr, DF-LMR,EPR	16

CO	$<5x10^{-17}$	300	$OH+CO_2$, DF-LMR	17
	$<2x10^{-17}$	298	DF-LMR	18
	$2x10^{-19}$	300	P	19
NO	$(8.3\pm0.1)x10^{-12}$	298	$OH+NO_2$, Review	1
	$3.7x10^{-12}exp(240\pm100/T)$	230-500	Review	1
O_3	$2.0x10^{-15}$	298	$OH+2O_2$, Review	1
	$1.4x10^{-14}exp(-600/T)$	250-400	Review	1
N_2O	$<5x10^{-17}$	300	DF-LMR	17
	$<2x10^{-20}$	298	DF-LMR	18
NO_2	$k_0=2.1x10^{-31}(T/300)^{-4.6}[O_2]$	200-300	HO_2NO_2, Review	1
	$k_0=2.3x10^{-31}(T/300)^{-4.6}[N_2]$	200-300	HO_2NO_2, Review	1
	$k_\infty=(4.2\pm2.5)x10^{-12}(T/300)^{0.2\pm1.0}$	200-300	HO_2NO_2, Review	1
	$<3x10^{-15}$	300	$HONO+O_2$, DF-LMR	20
SO_2	$<2x10^{-21}$	300	P	19
	$<2x10^{-17}$	298	DF-LMR	18
trans-2-butene	$<4x10^{-18}$	300	P	19
2,3-dimethyl-2-butene	$4x10^{-17}$	300	P	19
$O_2(a^1\Delta_g)$	$(1.7\pm0.8)x10^{-10}$	299-423	$H+2O_2$, DF-RA, LIF	21

SH

H	$\leq1.7x10^{-11}$	298	$S+H_2$, LP-LIF	22
Cl	$(1.1\pm0.3)x10^{-10}$	298	S+HCl, DF-MS	23
SH	$\leq1.7x10^{-11}$	298	LP-LIF	22
O_2	$\leq3.2x10^{-15}$	298	OH+SO, LP-LIF	22
	$\leq4x10^{-17}$	298	LP-LIF	24
NO	$(2.44\pm0.44)x10^{-31}[N_2]$	298	HSNO, LP-LIF	25
	$10^{-(24.42\pm0.94)}T^{-(2.48\pm0.36)}[N_2]$	250-445	HSNO, LP-LIF	25
	$k_\infty=(2.7\pm0.5)x10^{-11}$	250-300	HSNO, LP-LIF	25

NO_2	$(3.5\pm0.4)\times10^{-11}$	298	HSO+NO, LP-LIF	24
H_2S	$\leq1.7\times10^{-11}$	298	LP-LIF	22
C_2H_4	$\leq2.3\times10^{-15}$	298	LP-LIF	22
CS				
$O(^3P)$	$(2.06\pm0.14)\times10^{-11}$	305	CO+S, DF-PIMS	26
O_2	$(2.9\pm0.4)\times10^{-19}$	298	LP-LIF	27
	$<8\times10^{-17}$	300-670	DF-A	28
O_3	$(3.0\pm0.4)\times10^{-16}$	298	LP-LIF	27
NO_2	$(7.6\pm1.1)\times10^{-17}$	298	LP-LIF	27
SF				
SF	$(2.52\pm0.19)\times10^{-11}$	295	SF_2+S, DF-MS	23
$SO(X^3\Sigma^-)$				
OH	$(8.4\pm1.5)\times10^{-11}$	298	SO_2+H, DF-ESR	36
ClO	$(2.3\pm0.6)\times10^{-11}$	295	SO_2+Cl, DF-MS	29
BrO	$\geq4\times10^{-11}$	295	SO_2+Br, DF-MS	29
O_2	$6\times10^{-13}\exp(-3300\pm500/T)$	300-1000	SO_2+O, Review	3
	$(1.07\pm0.16)\times10^{-16}$	298	SO_2+O, LP-CL	30
	$(2.4^{+2.6}_{-0.9})\times10^{-13}\exp(-2370^{+200}_{-250}/T)$	230-420	SO_2+O, LP-CL	31
O_3	$4.5\times10^{-12}\exp(-1170\pm150/T)$	230-420	SO_2+O_2, Review	1
	$(1.06\pm0.16)\times10^{-13}$	298	SO_2+O_2, LP-Cl	30
	$(4.8^{+1.6}_{-0.8})\times10^{-12}\exp(-1170^{+80}_{-120}/T)$	230-420	LP-CL	31
	$(8.7\pm1.6)\times10^{-14}$	296	LP-CL	32
NO_2	$(1.48\pm0.20)\times10^{-11}$	298	SO_2+NO, LP-CL	30
	$(1.36\pm0.10)\times10^{-11}$	295	SO_2+NO, DF-MS	33
$SO(A^3\Pi)$				
Ar	$(7.5\pm1)\times10^{-12}$	298	DF-LIF-FQ	34

N_2	$(9 \pm 1) \times 10^{-12}$	298	DF-LIF-FQ	34
O_2	$(1.0 \pm 0.2) \times 10^{-10}$	298	DF-LIF-FQ	34
CS_2	$(5.2 \pm 0.4) \times 10^{-10}$	298	DF-LIF-FQ	34
SF_6	$(2.6 \pm 0.5) \times 10^{-11}$	298	DF-LIF-FQ	34
$HOSO_2$				
O_2	$(4 \pm 2) \times 10^{-13}$	298	HO_2+SO_3, FP-RF	35

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Table 3-7 Rate constants for radicals of group VII

Reactant	Rate constant ($cm^3 molecule^{-1} s^{-1}$)	Temp. (K)	Comments	Ref.
FO				
FO	1.5×10^{-11}	298	Review	1
NO	$(2.6 \pm 0.5) \times 10^{-11}$	298	$F+NO_2$, DF-MS	2
NO_2	$k_0 = 1.7 \times 10^{-31} (T/300)^{-3} [N_2]$	200-400	Review	1
	$k_\infty = 1.2 \times 10^{-11}$	200-400	Review	1
ClO				
$O(^3P)$	5.0×10^{-11}	298	O_2+Cl, Review	1
	$7.5 \times 10^{-11} \exp(-120/T)$	220-425		1
	$(3.6 \pm 0.7) \times 10^{-11}$	296	DF-RF	3
	$(5.0 \pm 1.0) \times 10^{-11} \exp(-96 \pm 20/T)$	236-422	FR-RF	3
	$(4.2 \pm 0.8) \times 10^{-11}$	298	DF-RF,A	4
	$(3.5 \pm 0.6) \times 10^{-11}$	298	DF-CL	5
OH	9.1×10^{-12}	298	Review	6
	$(1.17 \pm 0.33) \times 10^{-11}$	248-335	DF-RF	7
	$(1.19 \pm 0.9) \times 10^{-11}$	243-298	DF-RF	8
	$(8.o \pm 1.4) \times 10^{-12} \exp(235 \pm 46/T)$	219-373	DF-LMR	9
ClO	$(2.2 \pm 0.3) \times 10^{-14}$	298	1 Torr, DF-MS	10
	$(4.5 \pm 1) \times 10^{-15}$	298	Cl_2+O_2, 760Torr, MM -A	11
	$(3.1 \pm 0.8) \times 10^{-15}$	298	$Cl+ClO_2$, MM -A	11
	$(1.5 \pm 0.4) \times 10^{-15}$	298	Cl+OClO, MM -A	11
	$(9.8 \pm 0.4) \times 10^{-33} [Ar]$	298	Cl_2O_2, 70-600 Torr FP-A	12
	$7.8 \times 10^{-33} [He]$	298	Cl_2O_2, FP-A	12
	$2.2 \times 10^{-32} [O_2]$	298	Cl_2O_2, FP-A	12

NO	1.7×10^{-11}	298	$Cl+NO_2$, Review	6
	$6.2\times10^{-12}\exp(294/T)$	202-415	Review	6
NO_2	$k_0=1.6\times10^{-31}[N_2]$	298	Review	6
	$k_0=1.6\times10^{-31}(T/300)^{-3.4}[N_2]$	250-420	Review	6
ClOO				
Cl	1.7×10^{-10}	298	Cl_2+O_2,FP-A	13
	1.0×10^{-10}	298	2ClO,FP-A	13
BrO				
ClO	$(6.7\pm1.7)\times10^{-12}$	298	$Br+ClO_2$,DF-MS	14
BrO	$(2.17\pm0.68)\times10^{-12}$	298	BrO_2+Br,FP-A(UV)	15
	$9.58\times10^{-13}\exp(225\pm195/T)$	223-338	FP-A(UV)	15
HO_2	5×10^{-12}	298	Review	1
	$(5^{+5}_{-3})\times10^{-12}$	303	MM-A(UV)	16
NO	2.1×10^{-11}	298	$Br+NO_2$,Review	1
	$8.7\times10^{-12}\exp(260/T)$	224-425	Review	1
NO_2	$k_0=5.0\times10^{-31}[N_2]$	298	$BrONO_2$,Review	6
	$k_0=5.0\times10^{-31}(T/300)^{-3.0}[N_2]$	200-400	Review	6
O_3	$<4\times10^{-15}$	298	FP-A(UV)	15
IO				
IO	3×10^{-12}	298	Review	6
NO	$(2.8\pm0.2)\times10^{-11}$	298	$I+NO_2$,LP-LIF	17
	$(1.67\pm0.16)\times10^{-11}$	298	DF-MS	18
NO_2	$k_0=5.0\times10^{-31}(T/300)^{-3.0}[N_2]$	200-400	Review	6
	$k_\infty=2\times10^{-11}$	200-400	Review	6

SiH				
SiH_4	$(3\pm0.5)\times10^{-12}$	500	DF-LIF	19
SiH_3				
S_2Cl_2	$(2.4\pm0.5)\times10^{-11}$	326	LP-LMR	20
$SiCl_2$				
C_2H_4	$(1.3\pm0.3)\times10^{-13}$	298	FP-A(UV)	21
C_3H_6	$(3.8\pm1.0)\times10^{-13}$	298	FP-A(UV)	21
Si_2Cl_6	$<8.8\times10^{-13}$	298	FP-A(UV)	21
trans-C_3H_8	$(5.2\pm1.3)\times10^{-13}$	298	FP-A(UV)	21
C_2H_2	$(7.2\pm1.8)\times10^{-14}$	298	FP-A(UV)	21
1-C_4H_6	$(1.3\pm0.3)\times10^{-12}$	298	FP-A(UV)	21

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フリーラジカルの反応速度と分光学的及び熱力学的パラメーターに関する研究

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この論文は大気化学に関連の深い80種以上の原子及びフリーラジカルの反応速度と熱力学的パラメーター，さらにはレーザー誘起けい光法等の分光分析に有用な分光学的パラメーターの最新の最も信頼できる値をまとめたものである。これらのデータは光化学研究，反応研究，分光研究に役立つだけでなく，大気化学研究とそのシミュレーションに大いに役立つものである。内容は三章からなる。第一章は，フリーラジカルの分光定数で，30種の有機フリーラジカルと44種の無機フリーラジカルの基底状態の規準振動，許容励起状態のエネルギーと振動定数，レーザーけい光の有無，発光寿命の最新の値がまとめられている。特に，フリーラジカルの検出や反応の研究をレーザーけい光法で行う場合に便利なように全体を構成してある。また約170の論文が引用されている。

第二章にはフリーラジカルの生成熱が記されており，85種の原子及びフリーラジカルについて最も新しい生成熱の値がまとめられている。これらの値はフリーラジカルの反応を研究する際に極めて重要である。

第三章はフリーラジカルの関与する反応の速度定数をまとめたもので，70種以上のフリーラジカルの約1500の反応に対し常温での反応速度定数，活性化エネルギー，反応機構，反応速度測定の方法が記されている。引用文献は約350である。これらのデータは大気化学の反応のモデリングに不可欠な値である。まとめるに当たっては最も新しい最も信頼できる値を，その値の測定方法を考慮しながら厳正に選択した。

本論文は単にデータを羅列した資料集ではなく，大気化学・光化学・気相化学反応の研究を行う上で有用かつ信頼性の高いデータをピックアップし，分光分析や反応のモデリング等に利用しやすいようにまとめたものである。

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〔編集後記〕

現在，国立公害研究所が出版する刊行物のうち，調査研究の成果を総合的に報告するものとして「研究報告」（R－シリーズ）があり，野外調査基礎資料等の研究遂行に必要な情報は「研究資料」（B－シリーズ）として刊行されてきた。従って，本報文は「研究資料」として刊行することも考えられたが，その内容を編集委員会で検討した結果，

(1) 最新の研究の手法，成果，取り上げた定数等の精度に関し，この分野における従来のreview よりもレベルの高い情報を含んでいる

(2) review の手法自体に十分なオリジナリティがある

(3) この分野に関連する研究者は，「研究報告」として刊行されるほうがこの報文を利用して有用な情報が得易いと考えられる

と判断した。更にこの報文は国立公害研究所編集委員会の「査読要領細則」規程にある判断基準の多くの項目を満足しているので，この報文を「研究報告」として刊行することに決定した。　（編集委員会 委員長　廣崎昭太）

国立公害研究所特別研究成果報告

第 1 号　陸水域の富栄養化に関する総合研究 ── 霞ケ浦を対象域として ── 昭和51年度.（1977）

第 2 号　陸上植物による大気汚染環境の評価と改善に関する基礎的研究 ── 昭和51／52年度　研究報告.（1978）

（改　称）

国立公害研究所研究報告

※ 第 3 号　A comparative study of adults and immature stages of nine Japanese species of the genus *Chironomus* (Diptera, Chironomidae). (1978)
（日本産ユスリカ科　*Chironomus* 属9種の成虫，サナギ，幼虫の形態の比較）

第 4 号　スモッグチャンバーによる炭化水素－窒素酸化物系光化学反応の研究 ── 昭和52年度　中間報告.（1978）

第 5 号　芳香族炭化水素－窒素酸化物系の光酸化反応機構と光酸化二次生成物の培養細胞に及ぼす影響に関する研究 ── 昭和51，52年度　研究報告.（1978）

第 6 号　陸水域の富栄養化に関する総合研究（II）── 霞ケ浦を中心として. ── 昭和53年度.（1979）

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（日本産ユスリカ科20種の成虫，サナギ，幼虫の形態学的研究）

※ 第 8 号　大気汚染物質の単一および複合汚染の生体に対する影響に関する実験的研究 ── 昭和52，53年度　研究報告.（1979）

第 9 号　スモッグチャンバーによる炭化水素－窒素酸化物系光化学反応の研究 ── 昭和53年度　中間報告.（1979）

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（大気汚染物質の植物影響およびその植物毒性の機構に関する研究）

第12号　Multielement analysis studies by flame and inductively coupled plasma spectroscopy utilizing computer-controlled instrumentation. (1980)
（コンピュータ制御装置を利用したフレームおよび誘導結合プラズマ分光法による多元素同時分析）

第13号　Studies on chironomid midges of the Tama River. (1980)
Part 1. The distribution of chironomid species in a tributary in relation to the degree of pollution with sewage water.
Part 2. Description of 20 species of Chironominae recovered from a tributary.
（多摩川に発生するユスリカの研究
── 第1報　その一支流に見出されたユスリカ各種の分布と下水による汚染度との関係 ──
── 第2報　その一支流に見出された Chironominae 亜科の20種について ──）

第14号　有機廃棄物，合成有機化合物，重金属等の土壌生態系に及ぼす影響と浄化に関する研究 ── 昭和53，54年度　特別研究報告.（1980）

※ 第15号　大気汚染物質の単一および複合汚染の生体に対する影響に関する実験的研究 ── 昭和54年度　特別研究報告.（1980）

第16号　計測車レーザーレーダーによる大気汚染遠隔計測.（1980）

※ 第17号　流体の運動および輸送過程に及ぼす浮力効果 ── 臨海地域の気象特性と大気拡散現象の研究 ── 昭和53, 54年度　特別研究報告. (1980)

第18号　Preparation, analysis and certification of PEPPERBUSH standard reference material. (1980)
(環境標準試料「リョウブ」の調製, 分析および保証値)

※ 第19号　陸水域の富栄養化に関する総合研究 (III) ── 霞ヶ浦 (西浦) の湖流 ── 昭和53, 54年度. (1981)

第20号　陸水域の富栄養化に関する総合研究 (IV) ── 霞ヶ浦流域の地形, 気象水文特性およびその湖水環境に及ぼす影響 ── 昭和53, 54年度. (1981)

第21号　陸水域の富栄養化に関する総合研究 (V) ── 霞ヶ浦流入河川の流出負荷量変化とその評価 ── 昭和53, 54年度. (1981)

第22号　陸水域の富栄養化に関する総合研究 (VI) ── 霞ヶ浦の生態系の構造と生物現存量 ── 昭和53, 54年度. (1981)

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第27号　陸水域の富栄養化に関する総合研究 (XI) ── 研究総括 ── 昭和53, 54年度. (1981)

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第29号　Studies on chironomid midges of the Tama River. (1981)
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Part 4. Chironomidae recorded at a winter survey.
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── 第3報　夏期の調査で見出されたエリユスリカ亜科 Orthocladiinae 各種の記載と, その分布の下水汚染度との関係について ──
── 第4報　南浅川の冬期の調査で見出された各種の分布と記載 ──)

※ 第30号　海域における富栄養化と赤潮の発生機構に関する基礎的研究 ── 昭和54, 55年度　特別研究報告. (1982)

第31号　大気汚染物質の単一および複合汚染の生体に対する影響に関する実験的研究 ── 昭和55年度　特別研究報告. (1981)

第32号　スモッグチャンバーによる炭化水素－窒素酸化物系光化学反応の研究 ── 環境大気中における光化学二次汚染物質生成機構の研究 (フィールド研究1) ── 昭和54年度　特別研究中間報告. (1982)

第33号　臨海地域の気象特性と大気拡散現象の研究 ── 大気運動と大気拡散過程のシミュレーション ── 昭和55年度　特別研究報告. (1982)

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第36号　環境試料による汚染の長期モニタリング手法に関する研究 ── 昭和55, 56年度　特別研究報告. (1982)

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(環境標準試料「池底質」の調製，分析及び保証値)

第39号 環境汚染の遠隔計測・評価手法の開発に関する研究 — 昭和56年度 特別研究報告. (1982)

第40号 大気汚染物質の単一及び複合汚染の生体に対する影響に関する実験的研究 — 昭和56年度 特別研究報告. (1983)

※ 第41号 土壌環境の計測と評価に関する統計学的研究. (1983)

※ 第42号 底泥の物性及び流送特性に関する実験的研究. (1983)

※ 第43号 Studies on chironomid midges of the Tama River. (1983)
Part 5. An observation on the distribution of Chironominae along the main stream in June with description of 15 new species.
Part 6. Description of species of the subfamily Orthocladiinae recovered from the main stream in the June survey.
Part 7. Additional species collected in winter from the main stream.
(多摩川に発生するユスリカ類の研究
— 第5報 本流に発生するユスリカ類の分布に関する6月の調査成績とユスリカ亜科に属する15新種等の記録 —
— 第6報 多摩本流より6月に採集されたエリユスリカ亜科の各種について —
— 第7報 多摩本流より3月に採集されたユスリカ科の各種について —)

第44号 スモッグチャンバーによる炭化水素－窒素酸化物系光化学反応の研究 — 環境大気中における光化学二次汚染物質生成機構の研究（フィールド研究2）— 昭和54年度 特別研究中間報告. (1983)

第45号 有機廃棄物，合成有機化合物，重金属等の土壌生態系に及ぼす影響と浄化に関する研究 — 昭和53／55年度 特別研究総合報告. (1983)

第46号 有機廃棄物，合成有機化合物，重金属等の土壌生態系に及ぼす影響と浄化に関する研究 — 昭和54／55年度 特別研究報告 第1分冊. (1983)

第47号 有機廃棄物，合成有機化合物，重金属等の土壌生態系に及ぼす影響と浄化に関する研究 — 昭和54／55年度 特別研究報告 第2分冊. (1983)

※ 第48号 水質観測点の適正配置に関するシステム解析. (1983)

第49号 環境汚染の遠隔計測・評価手法の開発に関する研究 — 昭和57年度 特別研究報告. (1984)

※ 第50号 陸水域の富栄養化防止に関する総合研究（Ⅰ）— 霞ケ浦の流入負荷量の算定と評価 — 昭和55～57年度 特別研究報告. (1984)

※ 第51号 陸水域の富栄養化防止に関する総合研究（Ⅱ）— 霞ケ浦の物質循環とそれを支配する因子 — 昭和55～57年度 特別研究報告. (1984)

第52号 陸水域の富栄養化防止に関する総合研究（Ⅲ）— 霞ケ浦高浜入における隔離水界を利用した富栄養化防止手法の研究 — 昭和55～57年度 特別研究報告. (1984)

第53号 陸水域の富栄養化防止に関する総合研究（Ⅳ）— 霞ケ浦の魚類及び甲かく類現存量の季節変化と富栄養化 — 昭和55～57年度 特別研究報告. (1984)

第54号 陸水域の富栄養化防止に関する総合研究（Ⅴ）— 霞ケ浦の富栄養化現象のモデル化 — 昭和55～57年度 特別研究報告. (1984)

第55号 陸水域の富栄養化防止に関する総合研究（Ⅵ）— 富栄養化防止対策 — 昭和55～57年度 特別研究報告. (1984)

第56号 陸水域の富栄養化防止に関する総合研究（Ⅶ）— 湯ノ湖における富栄養化とその防止対策 — 昭和55～57年度 特別研究報告. (1984)

第57号 陸水域の富栄養化防止に関する総合研究（Ⅷ）— 総括報告 — 昭和55～57年度 特別研究

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第58号　環境試料による汚染の長期的モニタリング手法に関する研究――昭和55～57年度　特別研究総合報告.（1984）

第59号　炭化水素－窒素酸化物－硫黄酸化物系光化学反応の研究――光化学スモッグチャンバーによるオゾン生成機構の研究――大気中における有機化合物の光酸化反応機構の研究――昭和55～57年度　特別研究報告（第1分冊).（1984）

第60号　炭化水素－窒素酸化物－硫黄酸化物系光化学反応の研究――光化学エアロゾル生成機構の研究――昭和55～57年度　特別研究報告（第2分冊).（1984）

第61号　炭化水素－窒素酸化物－硫黄酸化物系光化学反応の研究――環境大気中における光化学二次汚染物質生成機構の研究（フィールド研究1）――昭和55～57年度　特別研究報告（第3分冊).（1984）

第62号　有害汚染物質による水界生態系のかく乱と回復過程に関する研究――昭和56～58年度　特別研究中間報告.（1984）

※第63号　海域における富栄養化と赤潮の発生機構に関する基礎的研究――昭和56年度　特別研究報告.（1984）

※第64号　複合大気汚染の植物影響に関する研究――昭和54～56年度　特別研究総合報告.（1984）

第65号　Studies on effects of air pollutant mixtures on plants――Part 1.（1984）
（複合大気汚染の植物に及ぼす影響――第1分冊）

※第66号　Studies on effects of air pollutant mixtures on plants――Part 2.（1984）
（複合大気汚染の植物に及ぼす影響――第2分冊）

第67号　環境中の有害物質による人の慢性影響に関する基礎的研究――昭和54～56年度　特別研究総合報告.（1984）

※第68号　汚泥の土壌還元とその環境影響に関する研究――昭和56～57年度　特別研究報告.（1984）

第69号　中禅寺湖の富栄養化現象に関する基礎的研究.（1984）

第70号　Studies on chironomid midges in lakes of the Nikko National Park（1984）
Part I. Ecological studies on chironomids in lakes of the Nikko National Park.
Part II. Taxonomical and morphological studies on the chironomid species collected from lakes in the Nikko National Park.
（日光国立公園の湖沼のユスリカに関する研究
――第1部　日光国立公園の湖のユスリカの生態学的研究――
――第2部　日光国立公園の湖沼に生息するユスリカ類の分類学的，形態学的研究――）

※第71号　リモートセンシングによる残雪及び雪田植生の分布解析.（1984）

第72号　炭化水素－窒素酸化物－硫黄酸化物系光化学反応の研究――環境大気中における光化学二次汚染物質生成機構の研究（フィールド研究2）――昭和55～57年度　特別研究報告（第4分冊).（1985）

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※第74号　都市域及びその周辺の自然環境に係る環境指標の開発に関する研究．環境指標――その考え方と作成方法――昭和59年度　特別研究報告.（1984）

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（琵琶湖底泥中の元素に関する陸水学及び環境化学的研究）

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第79号　Studies on the method for long term environmental monitoring – Research report 1980 -1982.（1985）
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第80号　海域における赤潮発生のモデル化に関する研究 —— 昭和57／58年度　特別研究報告.（1985）

第81号　環境影響評価制度の政策効果に関する研究 —— 地方公共団体の制度運用を中心として.（1985）

第82号　植物の大気環境浄化機能に関する研究 —— 昭和57～58年度　特別研究報告.（1985）

第83号　Studies on chironomid midges of some lakes in Japan.（1985）
（日本の湖沼のユスリカの研究）

第84号　重金属環境汚染による健康影響評価手法の開発に関する研究 —— 昭和57～59年度　特別研究総合報告.（1985）

第85号　Studies on the rate contants of Free radical reactions and related spectroscopic and thermochemical parameters
（フリーラジカルの反応速度と分光学的及び熱力学的パラメーターに関する研究）

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No. 1* Man activity and aquatic environment — with special references to Lake Kasumigaura — Progress report in 1976. (1977)

No. 2* Studies on evaluation and amelioration of air pollution by plants — Progress report in 1976-1977. (1978)

[Starting with Report No. 3, the new title for NIES Reports was changed to:]

Research Report from the National Institute for Environmental Studies

※ No. 3 A comparative study of adults and immature stages of nine Japanese species of the genus *Chironomus* (Diptera, Chironomidae). (1978)

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※ No. 7 A morphological study of adults and immature stages of 20 Japanese species of the family Chironomidae (Diptera). (1979)

※ No. 8* Studies on the biological effects of single and combined exposure of air pollutants — Research report in 1977-1978. (1979)

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No.10* Studies on evaluation and amelioration of air pollution by plants — Progress report in 1976-1978. (1979)

※ No.11 Studies on the effects of air pollutants on plants and mechanisms of phytotoxicity. (1980)

No.12 Multielement analysis studies by flame and inductively coupled plasma spectroscopy utilizing computer-controlled instrumentation. (1980)

No.13 Studies on chironomid midges of the Tama River. (1980)

Part 1. The distribution of chironomid species in a tributary in relation to the degree of pollution with sewage water.

Part 2. Description of 20 species of Chironominae recovered from a tributary.

No.14* Studies on the effects of organic wastes on the soil ecosystem — Progress report in 1978-1979. (1980)

※ No.15* Studies on the biological effects of single and combined exposure of air pollutants — Research report in 1977-1978. (1980)

No.16* Remote measurement of air pollution by a mobile laser radar. (1980)

※ No.17* Influence of buoyancy on fluid motions and transport processes — Meteorological characteristics and atmospheric diffusion phenomena in the coastal region — Progress report in 1978-1979. (1980)

No.18 Preparation, analysis and certification of PEPPERBUSH standard reference material. (1980)

※ No.19* Comprehensive studies on the eutrophication of fresh-water areas — Lake current of Kasumigaura (Nishiura) — 1978-1979. (1981)

No.20* Comprehensive studies on the eutrophication of fresh-water areas — Geomorphological and hydrometeorological characteristics of Kasumigaura watershed as related to the lake environment — 1978-1979. (1981)

No.21* Comprehensive studies on the eutrophication of fresh-water areas — Variation of pollutant load by influent rivers to Lake Kasumigaura — 1978-1979. (1981)

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No.23* Comprehensive studies on the eutrophication of fresh-water areas — Applicability of trophic state indices for lakes — 1978-1979. (1981)

No.24* Comprehensive studies on the eutrophication of fresh-water areas — Quantitative analysis of eutrophication effects on main utilization of lake water resources — 1978-1979. (1981)

No.25* Comprehensive studies on the eutrophication of fresh-water areas — Growth characteristics of Blue-Green Algae, *Mycrocystis* — 1978-1979. (1981)

No.26* Comprehensive studies on the eutrophication of fresh-water areas — Determination of argal growth potential by algal assay procedure — 1978-1979. (1981)

No.27* Comprehensive studies on the eutrophication of fresh-water areas — Summary of researches — 1978-1979. (1981)

No.28* Studies on effects of air pollutant mixtures on plants — Progress report in 1979-1980. (1981)

No.29 Studies on chironomid midges of the Tama River. (1981)

Part 3. Species on the subfamily Orthocladiinae recorded at the summer survey and their distribution in relation to the pollution with sewage waters.

Part 4. Chironomidae recorded at a winter survey.

※ No.30* Eutrophication and red tides in the coastal marine environment — Progress report in 1979-1980. (1982)

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No.33* Meteorological characteristics and atmospheric diffusion phenomena in the coastal region — Simulation of atmospheric motions and diffusion processes — Progress report in 1980. (1982)

※ No.34* The development and evaluation of remote measurement methods for environmental pollution — Research report in 1980. (1982)

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※ No.41* Statistical studies on methods of measurement and evaluation of chemical codition of soil — with special reference to heavy metals —. (1983)

※ No.42* Experimental studies on the physical properties of mud and the characteristics of mud transportation. (1983)

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Part 5. An observation on the distribution of Chironominae along the main stream in June, with description of 15 new species.

Part 6. Description of species of the subfamily Orthocladiinae recovered from the main stream in the June survey.

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No.47* Studies on the effect of organic wastes on the soil ecosystem — Research report in 1979 -1980, Part 2. (1983)

※ No.48* Study on optimal allocation of water quality monitoring points. (1983)

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※ No.50* Comprehensive studies on the eutrophication control of freshwaters — Estimation of input loading in Lake Kasumigaura — 1980-1982. (1984)

※ No.51* Comprehensive studies on the eutrophication control of freshwaters — The function of the ecosystem and significance of sediment in nutrient cycle in Lake Kasumigaura — 1980 -1982. (1984)

No.52* Comprehensive studies on the eutrophication control of freshwaters — Enclosure experiments for restoration of highly eutrophic shallow Lake Kasumigaura — 1980-1982. (1984)

No.53* Comprehensive studies on the eutrophication control of freshwaters — Seasonal changes of the biomass of fishes and crustacia in Lake Kasumigaura — 1980-1982. (1984)

No.54* Comprehensive studies on the eutrophication control of freshwaters — Modeling the eutrophication of Lake Kasumigaura — 1980-1982. (1984)

No.55* Comprehensive studies on the eutrophication control of freshwaters — Measures for eutrophication control — 1980-1982. (1984)

No.56* Comprehensive studies on the eutrophication control of freshwaters — Eutrophication in Lake Yunoko — 1980-1982. (1984)

No.57* Comprehensive studies on the eutrophication control of freshwaters — Summary of researches — 1980-1982. (1984)

No.58* Studies on the method for long term environmental monitoring — Outlines of special research project in 1980-1982. (1984)

No.59* Studies on photochemical reactions of hydrocarbon-nitrogen oxides-sulfer oxides system — Photochemical ozone formation studied by the evacuable smog chamber —

Atmosphpheric photooxidation mechanisms of selected organic compounds – Research report in 1980–1982. (1984)

No.60* Studies on photochemical reactions of hydrocarbon-nitrogen oxides-sulfer oxides system – Formation mechanisms of photochemical aerozol – Research report in 1980–1982. (1984)

No.61* Studies on photochemical reactions of hydrocarbon-nitrogen oxides-sulfer oxides system – Research on the photochemical secondary pollutants formation mechanism in the environmental atmosphere. – Research report in 1980–1982. (1984)

No.62 Effects of toxic substances on aquatic ecosystems – Progress report in 1980–1983. (1984)*

※ No.63* Eutrophication and red tides in the coastal marine environment – Progress report in 1981. (1984)

※ No.64* Studies on effects of air pollutant mixtures on plants – Final report in 1979–1981. (1984)

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※ No.68* Studies on the environmental effects of the application of sewage sludge to soil – Research report in 1981–1983. (1984)

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No.70 Studies on chironomid midges in lakes of the Nikko National Park – Part 1. Ecological studies on chronomids in lakes of the Nikko National Park. – Part II. Taxonomical and morphological studies on the chironomid species collected from lakes in the Nikko National Park. (1984)

※ No.71* Analysis on distributions of remnant snowpack and snow patch vegatation by remote sensing. (1984)

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No.73* Studies on photochemical reactions of hydrocarbon-nitrogen oxides-sulfur oxides-system – Final report in 1980–1982. (1985)

※ No.74* A comprehensive study on the development of indices system for urban and suburban environmental quality. Environmental indices-basic notion formation – Research report in 1984. (1984)

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No.77* The development and evaluation of remote measurement methods for environmental pollution. (1985)

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No.81* A study on effects of implementing environmental impact assessment procedure – With particular reference to implementation by local governments. (1985)

No.82* Studies on the role of vegetation as a sink of air pollutants – Research report in 1982 -1983. (1985)

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No.84* A comprehensive study on the development of assessment techniques for health effects due to environmental heavy metal exposure – Final report in 1982-1984. (1985)

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* in Japanese

※ out of stock