Table S1. The original chemical reaction mechanism with an assumption of a 200 m boundary layer. A constant temperature $T = 258$ K is assumed in the model, and the rate of third-body reactions is estimated as $k = k_\infty \times \frac{k_0/k_\infty}{(1+k_0/k_\infty)} \times F_c^{\frac{1}{1+(\log_{10}(k_0/k_\infty))^2}}$ (Atkinson et al., 2006).

Reaction Number	Reaction	k $[(\text{molec. cm}^{-3})^{1-n}\text{s}^{-1}]$	Order n	Reference
(R1)	$O_3 + h\nu \rightarrow O(^1D) + O_2$	4.70×10^{-7}	1	Lehrer et al. (2004)
(R2)	$O(^1D) + O_2 \rightarrow O_3$	$3.20\times10^{-11}\exp(67/T)$	2	Atkinson et al. (2006)
(R3)	$O(^1D) + N_2 \rightarrow O_3 + N_2$	$1.80\times10^{-11}\exp(107/T)$	2	Atkinson et al. (2006)
(R4)	$O(^1D) + H_2O \rightarrow 2OH$	2.20×10^{-10}	2	Atkinson et al. (2006)
(R5)	$Br + O_3 \rightarrow BrO + O_2$	$1.70\times10^{-11}\exp(-800/T)$	2	Atkinson et al. (2006)
(R6)	$Br_2 + h\nu \rightarrow 2Br$	0.021	1	Lehrer et al. (2004)
(R7)	$BrO + h\nu \xrightarrow{O_2} Br + O_3$	0.014	1	Lehrer et al. (2004)
(R8)	$BrO + BrO \rightarrow 2Br + O_2$	2.70×10^{-12}	2	Atkinson et al. (2006)
(R9)	$BrO + BrO \rightarrow Br_2 + O_2$	$2.90\times10^{-14}\exp(840/T)$	2	Atkinson et al. (2006)
(R10)	$BrO + HO_2 \rightarrow HOBr + O_2$	$4.5\times10^{-12}\exp(500/T)$	2	Atkinson et al. (2006)
(R11)	$HOBr + h\nu \rightarrow Br + OH$	3.00×10^{-4}	1	Lehrer et al. (2004)
(R12)	$CO + OH(+M) \xrightarrow{O_2} HO_2 + CO_2(+M)$	$1.44\times10^{-13}(1+\frac{[N_2]}{4\times10^{19}})$	2	Atkinson et al. (2006)
(R13)	$Br + HO_2 \rightarrow HBr + O_2$	$7.70\times10^{-12}\exp(-450/T)$	2	Atkinson et al. (2006)
(R14)	$HOBr + HBr \xrightarrow{\text{aerosol}} Br_2 + H_2O$	$(\frac{r}{D_g} + \frac{4}{v_{\text{therm}}\gamma})^{-1}\alpha_{\text{eff,aerosol}}$		Cao et al. (2014)
(R15)	$HOBr + H^+ + Br^- \xrightarrow{\text{ice}} Br_2 + H_2O$	$(r_a + r_b + r_c)^{-1}\alpha_{\text{eff,ice}}$		Cao et al. (2014)
(R16)	$Br + HCHO \xrightarrow{O_2} HBr + CO + HO_2$	$7.70\times10^{-12}\exp(-580/T)$	2	Atkinson et al. (2006)
(R17)	$Br + CH_3CHO \xrightarrow{O_2} HBr + CH_3CO_3$	$1.80\times10^{-11}\exp(-460/T)$	2	Atkinson et al. (2006)
(R18)	$Br_2 + OH \rightarrow HOBr + Br$	$2.0\times10^{-11}\exp(240/T)$	2	Atkinson et al. (2006)
(R19)	$HBr + OH \rightarrow H_2O + Br$	$5.50\times10^{-12}\exp(205/T)$	2	Atkinson et al. (2006)
(R20)	$Br + C_2H_2 \xrightarrow{3O_2} 2CO + 2HO_2 + Br$	4.20×10^{-14}	2	Borken (1996)
(R21)	$Br + C_2H_2 \xrightarrow{2O_2} 2CO + HO_2 + HBr$	8.92×10^{-14}	2	Borken (1996)
(R22)	$Br + C_2H_4 \xrightarrow{3.5O_2} 2CO + 2HO_2 + Br + H_2O$	2.52×10^{-13}	2	Barnes et al. (1993)
(R23)	$Br + C_2H_4 \xrightarrow{2.5O_2} 2CO + HO_2 + HBr + H_2O$	5.34×10^{-13}	2	Barnes et al. (1993)
(R24)	$CH_4 + OH \xrightarrow{O_2} CH_3O_2 + H_2O$	$1.85\times10^{-12}\exp(-1690/T)$	2	Atkinson et al. (2006)
(R25)	$BrO + CH_3O_2 \rightarrow Br + HCHO + HO_2$	1.60×10^{-12}	2	Aranda et al. (1997)
(R26)	$BrO + CH_3O_2 \rightarrow HOBr + HCHO + 0.5O_2$	4.10×10^{-12}	2	Aranda et al. (1997)
(R27)	$OH + O_3 \rightarrow HO_2 + O_2$	$1.70\times10^{-12}\exp(-940/T)$	2	Atkinson et al. (2006)
(R28)	$OH + HO_2 \rightarrow H_2O + O_2$	$4.80\times10^{-11}\exp(250/T)$	2	Atkinson et al. (2006)
(R29)	$OH + H_2O_2 \rightarrow HO_2 + H_2O$	$2.90\times10^{-12}\exp(-160/T)$	2	Atkinson et al. (2006)
(R30)	$OH + OH \xrightarrow{O_2} H_2O + O_3$	$6.20\times10^{-14}(T/298)^{2.6}\exp(945/T)$	2	Atkinson et al. (2006)
(R31)	$HO_2 + O_3 \rightarrow OH + 2O_2$	$2.03\times10^{-16}(T/300)^{4.57}\exp(693/T)$	2	Atkinson et al. (2006)
(R32)	$HO_2 + HO_2 \rightarrow O_2 + H_2O_2$	$2.20\times10^{-13}\exp(600/T)$	2	Atkinson et al. (2006)
(R33)	$C_2H_6 + OH \rightarrow C_2H_5 + H_2O$	$6.90\times10^{-12}\exp(-1000/T)$	2	Atkinson et al. (2006)
(R34)	$C_2H_5 + O_2 \rightarrow C_2H_4 + HO_2$	3.80×10^{-15}	2	Atkinson et al. (2006)
(R35)	$C_2H_5 + O_2(+M) \rightarrow C_2H_5O_2(+M)$	$k_0 = 5.90\times10^{-29}(T/300)^{-3.8}[N_2]$ $k_\infty = 7.80\times10^{-12}$ $F_c = 0.58\exp(-T/1250)$ $+0.42\exp(-T/183)$	2	Atkinson et al. (2006)
(R36)	$C_2H_4 + OH(+M) \xrightarrow{1.5O_2} CH_3O_2 + CO + H_2O(+M)$	$k_0 = 8.60\times10^{-29}(T/300)^{-3.1}[N_2]$ $k_\infty = 9.00\times10^{-12}(T/300)^{-0.85}$ $F_c = 0.48$	2	Atkinson et al. (2006)
(R37)	$C_2H_4 + O_3 \rightarrow HCHO + CO + H_2O$	4.33×10^{-19}	2	Sander et al. (1997)
(R38)	$C_2H_2 + OH(+M) \xrightarrow{1.5O_2} HCHO + CO + HO_2(+M)$	$k_0 = 5.00\times10^{-30}(T/300)^{-1.5}[N_2]$ $k_\infty = 1.00\times10^{-12}$ $F_c = 0.37$	2	Atkinson et al. (2006)
(R39)	$C_3H_8 + OH \xrightarrow{2O_2} C_2H_5O_2 + CO + 2H_2O$	$7.60\times10^{-12}\exp(-585/T)$	2	Atkinson et al. (2006)
(R40)	$HCHO + OH \xrightarrow{O_2} CO + H_2O + HO_2$	$5.40\times10^{-12}\exp(135/T)$	2	Atkinson et al. (2006)

Reaction Number	Reaction	k $[(\text{molec. cm}^{-3})^{1-n}\text{s}^{-1}]$	Order n	Reference
(R41)	$CH_3CHO + OH \xrightarrow{O_2} CH_3CO_3 + H_2O$	$4.40\times10^{-12}\exp(365/T)$	2	Atkinson et al. (2006)
(R42)	$CH_3O_2 + HO_2 \rightarrow CH_3O_2H + O_2$	$3.42\times10^{-13}\exp(780/T)$	2	Atkinson et al. (2006)
(R43)	$CH_3O_2 + HO_2 \rightarrow HCHO + H_2O + O_2$	$3.79\times10^{-14}\exp(780/T)$	2	Atkinson et al. (2006)
(R44)	$CH_3OOH + OH \rightarrow CH_3O_2 + H_2O$	$1.00\times10^{-12}\exp(190/T)$	2	Atkinson et al. (2006)
(R45)	$CH_3OOH + OH \rightarrow HCHO + OH + H_2O$	$1.90\times10^{-12}\exp(190/T)$	2	Atkinson et al. (2006)
(R46)	$CH_3OOH + Br \rightarrow CH_3O_2 + HBr$	$2.66\times10^{-12}\exp(-1610/T)$	2	Mallard et al. (1993)
(R47)	$CH_3O_2 + CH_3O_2 \rightarrow CH_3OH + HCHO + O_2$	$6.29\times10^{-14}\exp(365/T)$	2	Atkinson et al. (2006)
(R48)	$CH_3O_2 + CH_3O_2 \xrightarrow{O_2} 2HCHO + 2HO_2$	$3.71\times10^{-14}\exp(365/T)$	2	Atkinson et al. (2006)
(R49)	$CH_3OH + OH \xrightarrow{O_2} HCHO + HO_2 + H_2O$	$2.42\times10^{-12}\exp(-345/T)$	2	Atkinson et al. (2006)
(R50)	$C_2H_5O_2 + C_2H_5O_2 \rightarrow C_2H_5O + C_2H_5O + O_2$	6.40×10^{-14}	2	Atkinson et al. (2006)
(R51)	$C_2H_5O + O_2 \rightarrow CH_3CHO + HO_2$	7.44×10^{-15}	2	Sander et al. (1997)
(R52)	$C_2H_5O + O_2 \rightarrow CH_3O_2 + HCHO$	7.51×10^{-17}	2	Sander et al. (1997)
(R53)	$C_2H_5O_2 + HO_2 \rightarrow C_2H_5OOH + O_2$	$3.80\times10^{-13}\exp(900/T)$	2	Atkinson et al. (2006)
(R54)	$C_2H_5OOH + OH \rightarrow C_2H_5O_2 + H_2O$	8.21×10^{-12}	2	Sander et al. (1997)
(R55)	$C_2H_5OOH + Br \rightarrow C_2H_5O_2 + HBr$	5.19×10^{-15}	2	Sander et al. (1997)
(R56)	$OH + OH(+M) \longrightarrow H_2O_2(+M)$	$k_0 = 6.90\times10^{-31}(T/300)^{-0.8}[N_2]$	2	Atkinson et al. (2006)
		$k_\infty = 2.60\times10^{-11}$		
		$F_c = 0.50$		
(R57)	$H_2O_2 + h\nu \rightarrow 2OH$	2.00×10^{-6}	1	Lehrer et al. (2004)
(R58)	$HCHO + h\nu \xrightarrow{2O_2} 2HO_2 + CO$	5.50×10^{-6}	1	Lehrer et al. (2004)
(R59)	$HCHO + h\nu \rightarrow H_2 + CO$	9.60×10^{-6}	1	Lehrer et al. (2004)
(R60)	$C_2H_4O + h\nu \rightarrow CH_3O_2 + CO + +HO_2$	6.90×10^{-7}	1	Lehrer et al. (2004)
(R61)	$CH_3O_2H + h\nu \rightarrow OH + HCHO + HO_2$	1.20×10^{-6}	1	Lehrer et al. (2004)
(R62)	$C_2H_5O_2H + h\nu \rightarrow C_2H_5O + OH$	1.20×10^{-6}	1	Lehrer et al. (2004)
(R63)	$NO + O_3 \rightarrow NO_2 + O_2$	$1.40\times10^{-12}\exp(-1310/T)$	2	Atkinson et al. (2006)
(R64)	$NO + HO_2 \rightarrow NO_2 + OH$	$3.60\times10^{-12}\exp(270/T)$	2	Atkinson et al. (2006)
(R65)	$NO_2 + O_3 \rightarrow NO_3 + O_2$	$1.40\times10^{-13}\exp(-2470/T)$	2	Atkinson et al. (2006)
(R66)	$NO_2 + OH(+M) \rightarrow HNO_3(+M)$	$k_0 = 3.30\times10^{-30}(T/300)^{-3.0}[N_2]$	2	Atkinson et al. (2006)
		$k_\infty = 4.10\times10^{-11}$		
		$F_c = 0.40$		
(R67)	$NO + NO_3 \rightarrow 2NO_2$	$1.80\times10^{-11}\exp(110/T)$	2	Atkinson et al. (2006)
(R68)	$HONO + OH \rightarrow NO_2 + H_2O$	$2.50\times10^{-12}\exp(260/T)$	2	Atkinson et al. (2006)
(R69)	$HO_2 + NO_2(+M) \rightarrow HNO_4(+M)$	$k_0 = 1.80\times10^{-31}(T/300)^{-3.2}[N_2]$	2	Atkinson et al. (2006)
		$k_\infty = 4.70\times10^{-12}$		
		$F_c = 0.60$		
(R70)	$HNO_4(+M) \rightarrow NO_2 + HO_2(+M)$	$k_0 = 4.10\times10^{-5}\exp(-10650/T)[N_2]$	1	Atkinson et al. (2006)
		$k_\infty = 4.80\times10^{15}\exp(-11170/T)$		
		$F_c = 0.60$		
(R71)	$HNO_4 + OH \rightarrow NO_2 + H_2O + O_2$	$3.20\times10^{-13}\exp(690/T)$	2	Atkinson et al. (2006)
(R72)	$NO + OH(+M) \rightarrow HONO(+M)$	$k_0 = 7.40\times10^{-31}(T/300)^{-2.4}[N_2]$	2	Atkinson et al. (2006)
		$k_\infty = 3.30\times10^{-11}(T/300)^{-0.3}$		
		$F_c = 0.81$		
(R73)	$OH + NO_3 \rightarrow NO_2 + HO_2$	2.00×10^{-11}	2	Atkinson et al. (2006)
(R74)	$HNO_3 + h\nu \rightarrow NO_2 + OH$	4.40×10^{-8}	1	Lehrer et al. (2004)
(R75)	$NO_2 + h\nu \xrightarrow{O_2} NO + O_3$	3.50×10^{-3}	1	Lehrer et al. (2004)
(R76)	$NO_3 + h\nu \xrightarrow{O_2} NO_2 + O_3$	1.40×10^{-1}	1	Lehrer et al. (2004)
(R77)	$NO_3 + h\nu \rightarrow NO + O_2$	1.70×10^{-2}	1	Lehrer et al. (2004)
(R78)	$NO + CH_3O_2 \xrightarrow{O_2} HCHO + HO_2 + NO_2$	$2.30\times10^{-12}\exp(360/T)$	2	Atkinson et al. (2006)
(R79)	$NO_3 + CH_3OH \xrightarrow{O_2} HCHO + HO_2 + HNO_3$	$9.40\times10^{-13}\exp(-2650/T)$	2	Atkinson et al. (2006)
(R80)	$NO_3 + HCHO \xrightarrow{O_2} CO + HO_2 + HNO_3$	5.60×10^{-16}	2	Atkinson et al. (2006)

Reaction Number	Reaction	k $[(\text{molec. cm}^{-3})^{1-n}\text{s}^{-1}]$	Order n	Reference
(R81)	$NO + C_2H_5O_2 \xrightarrow{O_2} CH_3CHO + NO_2 + HO_2$	$2.60 \times 10^{-12}\exp(380/T)$	2	Atkinson et al. (2006)
(R82)	$NO + CH_3CO_3 \xrightarrow{O_2} CH_3O_2 + NO_2 + CO_2$	$7.50 \times 10^{-12}\exp(290/T)$	2	Atkinson et al. (2006)
(R83)	$NO_2 + CH_3CO_3(+M) \rightarrow PAN(+M)$	$k_0 = 2.70 \times 10^{-28}(T/300)^{-7.1}[N_2]$ $k_\infty = 1.20 \times 10^{-11}(T/300)^{-0.9}$ $F_c = 0.30$	2	Atkinson et al. (2006)
(R84)	$Br + NO_2(+M) \rightarrow BrNO_2(+M)$	$k_0 = 4.20 \times 10^{-31}(T/300)^{-2.4}[N_2]$ $k_\infty = 2.70 \times 10^{-11}$ $F_c = 0.55$	2	Atkinson et al. (2006)
(R85)	$Br + NO_3 \rightarrow BrO + NO_2$	1.60×10^{-11}	2	Atkinson et al. (2006)
(R86)	$BrO + NO_2(+M) \rightarrow BrONO_2(+M)$	$k_0 = 4.70 \times 10^{-31}(T/300)^{-3.1}[N_2]$ $k_\infty = 1.80 \times 10^{-11}$ $F_c = 0.40$	2	Atkinson et al. (2006)
(R87)	$BrO + NO \rightarrow Br + NO_2$	$8.70 \times 10^{-12}\exp(260/T)$	2	Atkinson et al. (2006)
(R88)	$BrONO_2 + h\nu \rightarrow NO_2 + BrO$	3.40×10^{-4}	1	Lehrer et al. (2004)
(R89)	$BrNO_2 + h\nu \rightarrow NO_2 + Br$	9.30×10^{-5}	1	Lehrer et al. (2004)
(R90)	$BrONO_2 + H_2O \xrightarrow{\text{aerosol}} HOBr + HNO_3$	$(\frac{r}{D_g} + \frac{4}{v_{\text{therm}}\gamma})^{-1}\alpha_{\text{eff,aerosol}}$		Cao et al. (2014)
(R91)	$PAN + h\nu \rightarrow NO_2 + CH_3CO_3$	6.79×10^{-7}	1	Fishman and Carney (1984)
(R92)	$BrONO_2 + H_2O \xrightarrow{\text{ice}} HOBr + HNO_3$	$(r_a + r_b + r_c)^{-1}\alpha_{\text{eff,ice}}$		Cao et al. (2014)

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