Electronic Supplementary Information:

Modeling Plasma-based CO_2 and CH_4 Conversion in Mixtures with N_2, O_2 and H_2O: the Bigger Plasma Chemistry Picture

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1 DESCRIPTION OF THE MODEL AND EXPERIMENTS

1.1 Zero-dimensional (0D) Chemical Kinetics Model and its Application to a DBD Reactor

We use a 0D chemical kinetics model, called ZDPlaskin, [1] to elucidate the plasma chemistry. In this model, the time-evolution of the species densities is calculated by balance equations, taking into account the various production and loss terms, as defined by chemical reactions.

$$\frac{dn_i}{dt} = \sum_j \left\{ \left(a_{ij}^{(2)} - a_{ij}^{(1)} \right) k_j \prod_l n_l^{a_{lj}^{(1)}} \right\} \quad \text{(S1)}$$

where $a_{ij}^{(1)}$ and $a_{ij}^{(2)}$ are the stoichiometric coefficients of species *i*, at the left and right hand side of a reaction *j*, respectively, n_l is the species density at the left-hand side of the reaction, and k_j is the rate coefficient of reaction *j* (see below).

Transport processes are neglected in this 0D model; hence, the species densities are assumed to be constant in the entire simulation volume. However, we can translate the temporal behavior into a spatial behavior (i.e., as a function of distance along the DBD tube) by means of the gas flow rate (i.e., similarity between batch reactor and plug flow reactor). This allows us to mimic the typical filamentary behavior of a DBD used for gas conversion. The gas molecules will pass through several microdischarge filaments on their way throughout the reactor. This is taken into account in the model by applying a large number of consecutive microdischarge pulses as a function of time, assuming a triangular pulse of power deposition, with a duration of 30 ns for each pulse. The maximum power of the pulse is chosen in such a manner that the total specific energy input (SEI) can be compared with experimental results for validation (see below). This approach has already proven to be applicable for a variety of conditions and gas mixtures. [2-6]

The rate coefficients of the heavy particle reactions (i.e., atoms, molecules, radicals, ions, excited species) depend on the gas temperature and are adopted from literature (see below), whereas the rate coefficients for the electron impact reactions are a function of the electron temperature and calculated with a Boltzmann solver, BOLSIG$^+$, [7] which is integrated into ZDPlaskin.

1.2 Description of the Experiments

For studying the multi-reforming process, dedicated experiments have been performed for further validation of the entire plasma chemistry set. The experimental apparatus consists of a temperature controlled DBD reactor, a power supply system, a reactant supply system, and measurement system, and is described in detail before. [8] The temperature-controlled DBD reactor is a coaxial DBD, composed of a quartz tube with inner diameter of 20 mm and length of 180 mm. A stainless-steel rod with diameter of 17.5 mm is used as high voltage (inner) electrode. A 45 mm wide stainless-steel mesh is wrapped around the tube to serve as grounded (outer) electrode. CH_4, CO_2, H_2O, O_2 and N_2 are used as feed gases with a constant total flow rate of 200 mL/min and several different combinations of individual flow rates (see next section). An adjustable high voltage AC power supply is connected to the reactor, and can supply voltage and current up to 20 kV and 30 mA. The discharge power was set to 10 W, providing a specific energy input (SEI) for all investigated cases of 0.76 eV/molecule and the reactor temperature remains constant at 673 K.

1.3 Definitions of Gas Conversion and Product Selectivities

The conversions of CO_2 and CH_4 are defined as:

$$X_{CO2} = \frac{\text{Moles of } CO_2 \text{converted}}{\text{Moles of } CO_2 \; input} \times 100\% \tag{S2}$$

$$X_{CH_4} = \frac{\text{Moles of } CH_4 \text{converted}}{\text{Moles of } CH_4 \; input} \times 100\% \tag{S3}$$

With the addition of H_2O and O_2, their conversions are defined as

$$X_{H_2O} = \frac{\text{Moles of } H_2O \text{ converted}}{\text{Moles of } H_2O \; input} \times 100\% \tag{S4}$$

$$X_{O_2} = \frac{\text{Moles of } O_2 \text{ converted}}{\text{Moles of } O_2 \; input} \times 100\% \tag{S5}$$

The selectivity of H_2, CO and hydrocarbons (C_xH_y) is defined as follows:

$$S_{H2} = \frac{\text{Moles of } H_2 \text{produced}}{2\times\text{Moles of } CH_4\ converted + \text{Moles of } H_2O\ converted} \times 100\% \tag{S6}$$

$$S_{\mathrm{CO}} = \frac{\text{Moles of CO produced}}{\text{Moles of } CH_4\ converted + \text{Moles of } CO_2\ converted} \times 100\% \tag{S7}$$

$$S_{\mathrm{C}_X\mathrm{H}_Y} = \frac{\text{x Moles of } \mathrm{C}_X\mathrm{H}_Y \text{ produced}}{\text{Moles of } CH_4\ converted + \text{Moles of } CO_2\ converted} \times 100\% \tag{S8}$$

2 OVERVIEW OF THE REACTIONS INCLUDED IN THE MODEL

Table S1. Electron impact reactions with the various molecules and radicals, included in the model. These reactions are treated by energy-dependent cross sections (or rate coefficients), and the references where these cross sections (or rate coefficients) were adopted from, are also included. For the vibrational and electronic excitations, several individual excitations are included, as indicated by the number between brackets.

CH_4													
Momentum Transfer	e^-	+	CH_4	→	e^-	+	CH_4						(9)
Vibrational Excitation or De-excitation	e^-	+	CH_4	→	e^-	+	$CH_4(v)$					(2)	(9)
Ionization	e^-	+	CH_4	→	$2e^-$	+	CH_4^+						(10)
Dissociative Ionization	e^-	+	CH_4	→	$2e^-$	+	CH_3^+	+	H				(10)
	e^-	+	CH_4	→	$2e^-$	+	CH_2^+	+	H_2				(10)
Dissociation	e^-	+	CH_4	→	e^-	+	CH_3	+	H				(11-12)
	e^-	+	CH_4	→	e^-	+	CH_2	+	H_2				(11-12)
	e^-	+	CH_4	→	e^-	+	CH	+	H_2	+	H		(11-12)
	e^-	+	CH_4	→	e^-	+	C	+	$2H_2$				(11-12)
CH_3													
Ionization	e^-	+	CH_3	→	$2e^-$	+	CH_3^+						(10)

Dissociative Ionization	$e^- + CH_3$	$\rightarrow$	$2e^-$	$+ CH_2^+$	$+ H$		(10)
	$e^- + CH_3$	$\rightarrow$	$2e^-$	$+ CH^+$	$+ H_2$		(10)
Dissociation	$e^- + CH_3$	$\rightarrow$	e^-	$+ CH_2$	$+ H$		(11-12)
	$e^- + CH_3$	$\rightarrow$	e^-	$+ CH$	$+ H_2$		(11-12)
CH_2							
Ionization	$e^- + CH_2$	$\rightarrow$	$2e^-$	$+ CH_2^+$			(10)
Dissociative Ionization	$e^- + CH_2$	$\rightarrow$	$2e^-$	$+ CH^+$	$+ H$		(10)
	$e^- + CH_2$	$\rightarrow$	$2e^-$	$+ C^+$	$+ H_2$		(10)
Dissociation	$e^- + CH_2$	$\rightarrow$	e^-	$+ CH$	$+ H$		(11-12)
CH							
Ionization	$e^- + CH$	$\rightarrow$	$2e^-$	$+ CH^+$			(10)
Dissociative Ionization	$e^- + CH$	$\rightarrow$	$2e^-$	$+ C^+$	$+ H$		(10)
Dissociation	$e^- + CH$	$\rightarrow$	e^-	$+ C$	$+ H$		(11-12)
C							
Ionization	$e^- + C$	$\rightarrow$	$2e^-$	$+ C^+$			(11-12)
C_2H_6							
Momentum Transfer	$e^- + C_2H_6$	$\rightarrow$	e^-	$+ C_2H_6$			(9)
Vibrational Excitation or De-excitation	$e^- + C_2H_6$	$\rightarrow$	e^-	$+ C_2H_6(v)$		(3)	(9)
Ionization	$e^- + C_2H_6$	$\rightarrow$	$2e^-$	$+ C_2H_6^+$			(10)
Dissociative Ionization	$e^- + C_2H_6$	$\rightarrow$	$2e^-$	$+ C_2H_5^+$	$+ H$		(10)

	$e^- + C_2H_6 \rightarrow 2e^- + C_2H_4^+ + H_2$		(10)
	$e^- + C_2H_6 \rightarrow 2e^- + C_2H_3^+ + H_2 + H$		(10)
	$e^- + C_2H_6 \rightarrow 2e^- + C_2H_2^+ + 2H_2$		(10)
	$e^- + C_2H_6 \rightarrow 2e^- + CH_3^+ + CH_3$		(10)
Dissociation	$e^- + C_2H_6 \rightarrow e^- + C_2H_5 + H$		(13-14)
	$e^- + C_2H_6 \rightarrow e^- + C_2H_4 + H_2$		(13-14)
C_2H_5			
Ionization	$e^- + C_2H_5 \rightarrow 2e^- + C_2H_5^+$		(10)
Dissociative Ionization	$e^- + C_2H_5 \rightarrow 2e^- + C_2H_4^+ + H$		(10)
	$e^- + C_2H_5 \rightarrow 2e^- + C_2H_3^+ + H_2$		(10)
	$e^- + C_2H_5 \rightarrow 2e^- + C_2H_2^+ + H_2 + H$		(10)
Dissociation	$e^- + C_2H_5 \rightarrow e^- + C_2H_4 + H$		(13-14)
	$e^- + C_2H_5 \rightarrow e^- + C_2H_3 + H_2$		(13-14)
C_2H_4			
Momentum Transfer	$e^- + C_2H_4 \rightarrow e^- + C_2H_4$		(9)
Vibrational Excitation or De-excitation	$e^- + C_2H_4 \rightarrow e^- + C_2H_4(v)$	(2)	(9)
Ionization	$e^- + C_2H_4 \rightarrow 2e^- + C_2H_4^+$		(10)
Dissociative Ionization	$e^- + C_2H_4 \rightarrow 2e^- + C_2H_3^+ + H$		(10)
	$e^- + C_2H_4 \rightarrow 2e^- + C_2H_2^+ + H_2$		(10)
Dissociation	$e^- + C_2H_4 \rightarrow e^- + C_2H_3 + H$		(13-14)
	$e^- + C_2H_4 \rightarrow e^- + C_2H_2 + H_2$		(13-14)
C_2H_3			

Ionization	e^-	+	C_2H_3	$\rightarrow$	$2e^-$	+	$C_2H_3^+$				(10)
Dissociative Ionization	e^-	+	C_2H_3	$\rightarrow$	$2e^-$	+	$C_2H_2^+$	+	H		(10)
	e^-	+	C_2H_3	$\rightarrow$	$2e^-$	+	C_2H^+	+	H_2		(10)
Dissociation	e^-	+	C_2H_3	$\rightarrow$	e^-	+	C_2H_2	+	H		(13-14)
	e^-	+	C_2H_3	$\rightarrow$	e^-	+	C_2H	+	H_2		(13-14)
C_2H_2											
Momentum Transfer	e^-	+	C_2H_2	$\rightarrow$	e^-	+	C_2H_2				(9)
Vibrational Excitation or De-excitation	e^-	+	C_2H_2	$\rightarrow$	e^-	+	$C_2H_2(v)$			(3)	(9)
Ionization	e^-	+	C_2H_2	$\rightarrow$	$2e^-$	+	$C_2H_2^+$				(10)
Dissociation	e^-	+	C_2H_2	$\rightarrow$	e^-	+	C_2H	+	H		(13-14)
	e^-	+	C_2H_2	$\rightarrow$	e^-	+	C_2	+	H_2		(13-14)
C_2H											
Ionization	e^-	+	C_2H	$\rightarrow$	$2e^-$	+	C_2H^+				(10)
Dissociation	e^-	+	C_2H	$\rightarrow$	e^-	+	C_2	+	H		(13-14)
	e^-	+	C_2H	$\rightarrow$	e^-	+	C	+	CH		(13-14)
C_2											
Momentum Transfer	e^-	+	C_2	$\rightarrow$	e^-	+	C_2				(15)
Ionization	e^-	+	C_2	$\rightarrow$	$2e^-$	+	C_2^+				(13-14)
Dissociation	e^-	+	C_2	$\rightarrow$	e^-	+	C	+	C		(13-14)
C											
Momentum Transfer	e^-	+	C	$\rightarrow$	e^-	+	C				(13-14)

Ionization	e^-	+ C	→	e^-	+ C^+			(13-14)
C_3H_8								
Momentum Transfer	e^-	+ C_3H_8	→	e^-	+ C_3H_8			(9)
Vibrational Excitation or De-excitation	e^-	+ C_3H_8	→	e^-	+ $C_3H_8(v)$		(2)	(9)
Dissociative	e^-	+ C_3H_8	→	$2e^-$	+ $C_2H_5^+$	+ CH_3		(10)
Ionization	e^-	+ C_3H_8	→	$2e^-$	+ $C_2H_4^+$	+ CH_4		(10)
Dissociation	e^-	+ C_3H_8	→	e^-	+ C_3H_7	+ H		(13-14)
	e^-	+ C_3H_8	→	e^-	+ C_3H_6	+ H_2		(13-14)
	e^-	+ C_3H_8	→	e^-	+ C_2H_4	+ CH_4		(13-14)
C_3H_7								
Dissociative Ionization	e^-	+ C_3H_7	→	$2e^-$	+ $C_2H_5^+$	+ CH_2		(13-14)
	e^-	+ C_3H_7	→	$2e^-$	+ $C_2H_4^+$	+ CH_3		(13-14)
	e^-	+ C_3H_7	→	$2e^-$	+ $C_2H_3^+$	+ CH_4		(13-14)
	e^-	+ C_3H_7	→	$2e^-$	+ CH_3^+	+ C_2H_4		(13-14)
Dissociation	e^-	+ C_3H_7	→	e^-	+ C_3H_6	+ H		(13-14)
	e^-	+ C_3H_7	→	e^-	+ C_2H_4	+ CH_3		(13-14)
	e^-	+ C_3H_7	→	e^-	+ C_2H_3	+ CH_4		(13-14)
	e^-	+ C_3H_7	→	e^-	+ C_3H_5	+ H_2		(13-14)
C_3H_6								
Dissociative Ionization	e^-	+ C_3H_6	→	$2e^-$	+ $C_2H_5^+$	+ CH		(13-14)
	e^-	+ C_3H_6	→	$2e^-$	+ $C_2H_4^+$	+ CH_2		(13-14)
	e^-	+ C_3H_6	→	$2e^-$	+ $C_2H_3^+$	+ CH_3		(13-14)

	e^-	+ C_3H_6	→	$2e^-$	+	$C_2H_2^+$	+ CH_4			(13-14)
	e^-	+ C_3H_6	→	$2e^-$	+	CH_3^+	+ C_2H_3			(13-14)
Dissociation	e^-	+ C_3H_6	→	e^-	+	C_3H_5	+ H			(13-14)
	e^-	+ C_3H_6	→	e^-	+	C_2H_2	+ CH_4			(13-14)
C_3H_5										
Dissociative Ionization	e^-	+ C_3H_5	→	$2e^-$	+	$C_2H_3^+$	+ CH_2			(13-14)
	e^-	+ C_3H_5	→	$2e^-$	+	$C_2H_2^+$	+ CH_3			(13-14)
	e^-	+ C_3H_5	→	$2e^-$	+	CH_3^+	+ C_2H_2			(13-14)
Dissociation	e^-	+ C_3H_5	→	e^-	+	C_2H_2	+ CH_3			(13-14)
H_2										
Momentum Transfer	e^-	+ H_2	→	e^-	+	H_2				(16)
Rotational Excitation	e^-	+ H_2	→	e^-	+	$H_2(r)$			(2)	(16)
Vibrational Excitation	e^-	+ H_2	↔	e^-	+	$H_2(v)$			(3)	(16)
Electronic Excitation	e^-	+ H_2	→	e^-	+	$H_2(e)$			(10)	(16)
Ionization	e^-	+ H_2	→	$2e^-$	+	H_2^+				(16)
Dissociation	e^-	+ H_2	→	e^-	+	2H				(16)
$H_2(v,e)$										
Momentum Transfer	e^-	+ $H_2(v,e)$	→	e^-	+	$H_2(v,e)$				(16)
Ionization	e^-	+ $H_2(v,e)$	→	$2e^-$	+	H_2^+				(16)
Dissociation	e^-	+ $H_2(v,e)$	→	e^-	+	2H				(16)
H										

Momentum Transfer	$e^- + H$	$\rightarrow$	$e^- + H$			(17)
Electronic excitation	$e^- + H$	$\leftrightarrow$	$e^- + H(e)$			(17)
Ionization	$e^- + H$	$\rightarrow$	$2e^- + H^+$			(17)
H(e)						
Momentum Transfer	$e^- + H(e)$	$\rightarrow$	$e^- + H(e)$			(17)
Ionization	$e^- + H(e)$	$\rightarrow$	$2e^- + H^+$			(17)
O_2						
Momentum Transfer	$e^- + O_2$	$\rightarrow$	$e^- + O_2$			(18)
Vibrational Excitation	$e^- + O_2$	$\rightarrow$	$e^- + O_2(v)$		(4)	(18)
Electronic Excitation	$e^- + O_2$	$\rightarrow$	$e^- + O_2(a1)$			(18)
	$e^- + O_2$	$\rightarrow$	$e^- + O_2(b1)$			(18)
Ionization	$e^- + O_2$	$\rightarrow$	$2e^- + O_2^+$			(18)
Dissociative Ionization	$e^- + O_2$	$\rightarrow$	$2e^- + O^+$	$+ O$		(19)
Attachment	$e^- + O_2 + M$	$\rightarrow$	$O_2^- + M$			(18)
Dissociative Attachment	$e^- + O_2$	$\rightarrow$	$O^- + O$			(18)
Ion-pair formation	$e^- + O_2$	$\rightarrow$	$e^- + O^+$	$+ O^-$	Energy dependent rate coefficient	(20)
Dissociation	$e^- + O_2$	$\rightarrow$	$e^- + 2O$		(2)	(18)

O_2(a1)			
Momentum Transfer	$e^- + O_2(a1) \rightarrow e^- + O_2(a1)$		(18)
Electronic Excitation	$e^- + O_2(a1) \rightarrow e^- + O_2(b1)$		(18)
Ionization	$e^- + O_2(a1) \rightarrow 2e^- + O_2^+$		(18)
Dissociative Ionization	$e^- + O_2(a1) \rightarrow 2e^- + O^+ + O$		(19)
Attachment	$e^- + O_2(a1) + M \rightarrow O_2^- + M$		(18)
Dissociative Attachment	$e^- + O_2(a1) \rightarrow O^- + O$		(18)
Ion-pair formation	$e^- + O_2(a1) \rightarrow e^- + O^+ + O^-$	Energy dependent rate coefficient	(20)
Dissociation	$e^- + O_2(a1) \rightarrow e^- + 2O$	(2)	(18)
O_2(b1)			
Momentum Transfer	$e^- + O_2(b1) \rightarrow e^- + O_2(b1)$		(18)
Electronic Excitation	$e^- + O_2(b1) \rightarrow e^- + O_2(a1)$		(18)
Ionization	$e^- + O_2(b1) \rightarrow 2e^- + O_2^+$		(18)
Dissociative Ionization	$e^- + O_2(b1) \rightarrow 2e^- + O^+ + O$		(19)
Attachment	$e^- + O_2(b1) + M \rightarrow O_2^- + M$		(18)
Dissociative Attachment	$e^- + O_2(b1) \rightarrow O^- + O$		(18)
Ion-pair	$e^- + O_2(b1) \rightarrow e^- + O^+ + O^-$	Energy	(20)

formation		dependent rate coefficient	
Dissociation	$e^- + O_2(b1) \rightarrow e^- + 2O$	(2)	(18)
O			
Momentum Transfer	$e^- + O \rightarrow e^- + O$		(21)
Electronic Excitation	$e^- + O \leftrightarrow e^- + O(1D)$		(21)
	$e^- + O \leftrightarrow e^- + O(1S)$		(21)
Ionization	$e^- + O \rightarrow 2e^- + O^+$		(21)
Attachment	$e^- + O + M \rightarrow O^- + M$	1.00×10^{-31} $cm^6\ s^{-1}$	(19)
O(1D)			
Momentum Transfer	$e^- + O(1D) \rightarrow e^- + O(1D)$		(21)
Electronic Excitation	$e^- + O(1D) \leftrightarrow e^- + O(1S)$		(21)
Ionization	$e^- + O(1D) \rightarrow 2e^- + O^+$		(21)
Attachment	$e^- + O(1D) + M \rightarrow O^- + M$	1.00×10^{-31} $cm^6\ s^{-1}$	(19)
O_3			
Momentum Transfer	$e^- + O_3 \rightarrow e^- + O_3$		(21)
Dissociative Ionization	$e^- + O_3 \rightarrow 2e^- + O_2^+ + O$		(19)
Attachment	$e^- + O_3 + O_2 \rightarrow O_3^- + O_2$	Energy dependent	(22)

												rate coefficient	
Dissociative Attachment	e^-	+	O_3	→	O^-	+	O_2						(23)
	e^-	+	O_3	→	O_2^-	+	O						(23)
Ion-pair formation	e^-	+	O_3	→	e^-	+	O^-	+	O^+	+	O		(19)
Dissociation	e^-	+	O_3	→	e^-	+	O_2	+	O			Energy dependent rate coefficient	(19)
CO_2													
Momentum Transfer	e^-	+	CO_2	→	e^-	+	CO_2						(24-25)
Vibrational Excitation	e^-	+	CO_2	→	e^-	+	$CO_2(v)$					(3)	(24-25)
Electronic Excitation	e^-	+	CO_2	↔	e^-	+	$CO_2(e1)$						(24-25)
	e^-	+	CO_2	↔	e^-	+	$CO_2(e2)$						(24-25)
Ionization	e^-	+	$CO_2(g, e)$	→	$2e^-$	+	CO_2^+						(24-25)
Dissociative Attachment	e^-	+	$CO_2(g, e)$	→	O^-	+	CO						(24-25)
Dissociation	e^-	+	$CO_2(g, e)$	→	e^-	+	CO	+	O				(26)
Dissociative Ionization	e^-	+	$CO_2(g, e)$	→	e^-	+	O	+	CO^+				(27)
	e^-	+	$CO_2(g, e)$	→	e^-	+	CO	+	O^+				(27)
	e^-	+	$CO_2(g, e)$	→	e^-	+	O_2	+	C^+				(27)
CO													

Momentum Transfer	e^-	+ CO	→	e^-	+	CO			(28)
Vibrational Excitation	e^-	+ CO	→	e^-	+	CO(v)		(1)	(28)
Electronic Excitation	e^-	+ CO	→	e^-	+	CO(e)		(5)	(28)
Ionization	e^-	+ CO	→	$2e^-$	+	CO^+			(28)
Dissociative Ionization	e^-	+ CO	→	e^-	+	O	+ C^+		(28-29)
	e^-	+ CO	→	e^-	+	C	+ O^+		(28-29)
Dissociative Attachment	e^-	+ CO	→	O^-	+	C			(28)
Dissociation	e^-	+ CO	→	e^-	+	C	+ O		(28)
H_2O									
Momentum Transfer	e^-	+ H_2O	→	e^-	+	H_2O			(30)
Vibrational Excitation	e^-	+ H_2O	→	e^-	+	H_2O (v)		(2)	(30)
Dissociative Attachment	e^-	+ H_2O	→	O^-	+	H_2			(30)
	e^-	+ H_2O	→	OH^-	+	H			(30)
Dissociation	e^-	+ H_2O	→	e^-	+	OH	+ H		(30)
	e^-	+ H_2O	→	e^-	+	O	+ H_2		(30)
	e^-	+ H_2O	→	e^-	+	O	+ 2H		(30)
Ionization	e^-	+ H_2O	→	$2e^-$	+	H_2O^+			(30)
OH									
Momentum Transfer	e^-	+ OH	→	e^-	+	OH			(31)

Ionization	e^-	+	OH	$\rightarrow$	$2e^-$	+	OH^+			Energy dependent rate coefficient	(32)
Dissociation	e^-	+	OH	$\rightarrow$	e^-	+	O	+	H	Energy dependent rate coefficient	(32)
OH^-											
Momentum Transfer	e^-	+	OH^-	$\rightarrow$	e^-	+	OH^-				(33)
Ionization	e^-	+	OH^-	$\rightarrow$	$2e^-$	+	OH				(33)
Dissociative Ionization	e^-	+	OH^-	$\rightarrow$	$2e^-$	+	O	+	H	1.95×10^{-8} cm^3s^{-1}	(32)
N_2											
Momentum Transfer	e^-	+	N_2	$\rightarrow$	e^-	+	N_2				(34)
Rotational Excitation	e^-	+	N_2	$\rightarrow$	e^-	+	$N_2(r)$			(1)	(34)
Vibrational Excitation	e^-	+	N_2	$\leftrightarrow$	e^-	+	$N_2(v)$			(8)	(34)
Electronic Excitation	e^-	+	N_2	$\leftrightarrow$	e^-	+	$N_2(a'\Sigma_u^-)$				(34)
	e^-	+	N_2	$\leftrightarrow$	e^-	+	$N_2(A^3\Sigma_u^+)$				(34)
	e^-	+	N_2	$\leftrightarrow$	e^-	+	$N_2\left(B^3\Pi_g\right)$				(34)
	e^-	+	N_2	$\leftrightarrow$	e^-	+	$N_2(C^3\Pi_u)$				(34)
Ionization	e^-	+	N_2	$\rightarrow$	$2e^-$	+	N_2^+				(34)

Dissociative Ionization	e^-	+ N_2	→	e^-	+ N	+ N^+		(34)
N_2(v)								
Momentum Transfer	e^-	+ $N_2(v)$	→	e^-	+ $N_2(v)$			(34)
Rotational Excitation	e^-	+ $N_2(v)$	→	e^-	+ $N_2(r)$		(1)	(34)
Electronic Excitation	e^-	+ $N_2(v)$	→	e^-	+ $N_2(a'\Sigma_u^-)$			(34)
	e^-	+ $N_2(v)$	→	e^-	+ $N_2(A^3\Sigma_u^+)$			(34)
	e^-	+ $N_2(v)$	→	e^-	+ $N_2(B^3\Pi_g)$			(34)
	e^-	+ $N_2(v)$	→	e^-	+ $N_2(C^3\Pi_u)$			(34)
Ionization	e^-	+ $N_2(v)$	→	$2e^-$	+ N_2^+			(34)
Dissociative Ionization	e^-	+ $N_2(v)$	→	e^-	+ N	+ N^+		(34)
Dissociation	e-	+ $N_2(v)$	→	e-	+ N	+ N		(34)
N_2 (e) ($N_2(a'\Sigma_u^-)$, $N_2(C^3\Pi_u)$, $N_2(A^3\Sigma_u^+)$, $N_2(B^3\Pi_g)$)								
Momentum Transfer	e-	+ $N_2(e)$	→	e-	+ $N_2(e)$			(34)
Rotational Excitation	e-	+ $N_2(e)$	→	e-	+ $N_2(r)$		(1)	(34)
Ionization	e-	+ $N_2(e)$	→	2e-	+ N_2^+			(34)
Dissociative Ionization	e-	+ $N_2(e)$	→	e-	+ N	+ N^+		(34)
Dissociation	e-	+ $N_2(e)$	↔	e-	+ N	+ N		(34)
N								

Momentum Transfer	e- + N → e- + N		(35)
Electronic Excitation	e- + N ↔ e- + N(2D)		(36)
	e- + N ↔ e- + N(2S)		(36)
Ionization	e- + N → 2e- + N^+		(37)
N(2D)			
Momentum Transfer	e- + $N(^2D)$ → e- + N(2D)		(35)
Electronic Excitation	e- + N(2D) ↔ e- + N(2S)		(36)
Ionization	e- + N(2D) → 2e- + H+		(37)
NH			
Momentum Transfer	e- + NH → e- + NH		(38)
Dissociation	e- + NH → e- + N + H		(38)
Dissociative Ionization	e- + NH → 2e- + N^+ + H		(39)
NO			
Momentum Transfer	e^- + NO → e^- + NO		(21)
Vibrational Excitation	e^- + NO → e^- + NO(v)	(6)	(21)
Electronic Excitation	e- + NO → e- + NO(e)	(3)	(21)
Ionization	e- + NO → 2e- + NO^+		(40)
Dissociative Ionization	e- + NO → 2e- + N^+ + O		(40)

	e- + NO → 2e- + O^+ + N		(40)
Dissociation	e- + NO → e- + N + O		(41)
Dissociative Attachment	e^- + NO → O^- + N		(42)
NO_2			
Momentum Transfer	e- + NO_2 → e- + NO_2		(43)
Ionization	e- + NO_2 → 2e- + NO_2^+		(44)
Dissociative Ionization	e- + NO_2 → 2e- + NO^+ + O		(44)
Dissociation	e- + NO_2 → e- + NO + O		(45)
N_2O			
Momentum Transfer	e- + N_2O → e- + N_2O		(46)
Vibrational Excitation	e^- + N_2O → e^- + N_2O(v)	(3)	(46)
Electronic Excitation	e- + N_2O → e- + N_2O (e)	(3)	(46)
Dissociative Attachment	e^- + N_2O → N_2 + O^-		(46)
Dissociative Ionization	e^- + N_2O → 2e- + NO^+ + N		(47)
	e- + N_2O → 2e- + O^+ + N_2		(47)
	e- + N_2O → 2e- + N_2^+ + O		(47)
	e- + N_2O → 2e- + N^+ + NO		(47)

Dissociation	e-	+	N_2O	→	e-	+	N_2	+	O	Energy dependent rate coefficient	(45)
	e-	+	N_2O	→	e-	+	NO	+	N	Energy dependent rate coefficient	(45)
	e-	+	N_2O	→	e-	+	N_2	+	O(1 D)	Energy dependent rate coefficient	(45)
H^-											
Momentum Transfer	e^-	+	H^-	→	e^-	+	H^-				(45)
Ionization	e^-	+	H^-	→	$2e^-$	+	H				(48)
H_2^+											
Momentum Transfer	e-	+	H_2^+	→	e-	+	H_2^+				(45)
Dissociation	e-	+	H_2^+	→	e-	+	H^+	+	H		(49)
Dissociative Attachment	e^-	+	H_2^+	→	H^+	+	H^-				(50)
H_3^+											
Momentum Transfer	e-	+	H_3^+	→	e-	+	H_3^+				(45)
Dissociation	e-	+	H_3^+	→	e-	+	H^+	+	H_2		(49)
	e-	+	H_3^+	→	e-	+	H^+	+	2H		(50)

Table S2. Electron-ion recombination reactions included in the model and the references where these data were adopted from. Some reactions are treated by energy-dependent cross sections, for others the rate coefficients are given by expressions, where T_e is the electron temperature in K and T_g is the gas temperature in K. Note a means "estimated value". The rate constants are in cm^3 s^{-1} or cm^6 s^{-1} for binary or ternary reactions, respectively.

e^-	+	CH_5^+	→	CH_3	+	2H			$2.57 \times 10^{-7}(T_e/300)^{-0.30}$	(11,51)
e^-	+	CH_5^+	→	CH_2	+	H_2	+	H	$6.61 \times 10^{-8}(T_e/300)^{-0.30}$	(11,51)
e^-	+	CH_4^+	→	CH_3	+	H			$1.18 \times 10^{-8}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_4^+	→	CH_2	+	2H			$2.42 \times 10^{-8}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_4^+	→	CH	+	H_2	+	H	$1.41 \times 10^{-8}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_3^+	→	CH_2	+	H			$2.25 \times 10^{-8}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_3^+	→	CH	+	H_2			$7.88 \times 10^{-9}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_3^+	→	CH	+	2H			$9.00 \times 10^{-9}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_3^+	→	C	+	H_2	+	H	$1.69 \times 10^{-8}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_2^+	→	CH	+	H			$1.00 \times 10^{-8}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_2^+	→	C	+	H_2			$4.82 \times 10^{-9}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH_2^+	→	C	+	2H			$2.53 \times 10^{-8}(T_e/300)^{-0.50}$	(11,51)
e^-	+	CH^+	→	C	+	H			$3.23 \times 10^{-8}(T_e/300)^{-0.42}$	(11,51)
e^-	+	$C_2H_6^+$	→	C_2H_5	+	H			$2.19 \times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_6^+$	→	C_2H_4	+	2H			$3.36 \times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_5^+$	→	C_2H_4	+	H			$7.70 \times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_5^+$	→	C_2H_3	+	2H			$1.92 \times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_5^+$	→	C_2H_2	+	H_2	+	H	$1.60 \times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_5^+$	→	C_2H_2	+	3H			$8.98 \times 10^{-9}(T_g/300)^{-0.71}$	(14)
e^-	+	$C_2H_5^+$	→	CH_3	+	CH_2			$9.62 \times 10^{-9}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_4^+$	→	C_2H_3	+	H			$8.29 \times 10^{-9}(T_e/300)^{-0.71}$	(14)

e^-	+	$C_2H_4^+$			→	C_2H_2	+	2H			$3.43\times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_4^+$			→	C_2H	+	H_2	+	H	$5.53\times 10^{-9}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_3^+$			→	C_2H_2	+	H			$1.34\times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_3^+$			→	C_2H	+	2H			$2.74\times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_2^+$			→	C_2H	+	H			$1.87\times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_2^+$			→	C_2	+	2H			$1.12\times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	$C_2H_2^+$			→	2CH					$4.87\times 10^{-9}(T_e/300)^{-0.71}$	(14)
e^-	+	C_2H^+			→	C_2	+	H			$1.34\times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	C_2H^+			→	CH	+	C			$1.09\times 10^{-8}(T_e/300)^{-0.71}$	(14)
e^-	+	C_2H^+			→	H	+	2C			$4.29\times 10^{-9}(T_e/300)^{-0.71}$	(14)
e^-	+	H_3^+			→	3H					f(σ)	(50)
e^-	+	H_3^+			→	H_2	+	H			f(σ)	(50)
e^-	+	H^+			→	H					f(σ)	(45)
$2e^-$	+	H^+			→	e^-	+	H			$8.80\times 10^{-27}(T_e/11604.5)^{-4.50}$	(52)
e^-	+	H_2^+			→	2H					f(σ)	(49)
e^-	+	O^+	+	M	→	O	+	M			$6.00\times 10^{-27}(T_e/300)^{-1.50}$	(22)
e^-	+	N^+	+	M	→	N	+	M			$6.00\times 10^{-27}(T_e/300)^{-1.50}$	(22)
e^-	+	O_2^+	+	M	→	O_2	+	M			$6.00\times 10^{-27}(T_e/300)^{-1.50}$	(22)
e^-	+	NO^+	+	M	→	NO	+	M			$6.00\times 10^{-27}(T_e/300)^{-1.50}$	(22)
e^-	+	N_2^+	+	M	→	N_2	+	M			$6.00\times 10^{-27}(T_e/300)^{-1.50}$	(22)
e^-	+	O^+	+	e^-	→	O	+	e^-			$7.20\times 10^{-20}(T_e/300)^{-4.50}$	(53)
e^-	+	N^+	+	e^-	→	N	+	e^-			$7.20\times 10^{-20}(T_e/300)^{-4.50}$	(53)
e^-	+	O_2^+	+	e	→	O_2	+	e			$1.00\times 10^{-19}(T_e/300)^{-4.50}$	(22)
e^-	+	NO^+	+	e	→	NO	+	e			$1.00\times 10^{-19}(T_e/300)^{-4.50}$	(22)
e^-	+	N_2^+	+	e	→	N_2	+	e			$1.00\times 10^{-19}(T_e/300)^{-4.50}$	(22)

e^-	+	O_2^+	→	O	+	O	$1.49\times 10^{-7}(T_e/300)^{-0.70}$	(53)
e^-	+	O_2^+	→	O	+	O(1D)	$1.08\times 10^{-7}(T_e/300)^{-0.70}$	(53)
e^-	+	O_2^+	→	O	+	O(1S)	$0.14\times 10^{-7}(T_e/300)^{-0.70}$	(53)
e^-	+	N_2^+	→	N	+	N	$0.90\times 10^{-7}(T_e/300)^{-0.39}$	(53)
e^-	+	N_2^+	→	N	+	N(2D)	$0.81\times 10^{-7}(T_e/300)^{-0.39}$	(53)
e^-	+	N_2^+	→	N	+	N(2P)	$0.09\times 10^{-7}(T_e/300)^{-0.39}$	(53)
e^-	+	O_4^+	→	O_2	+	O_2	$1.40\times 10^{-6}(T_e/300)^{-0.70}$	(22)
e^-	+	NO^+	→	O	+	N	$0.84\times 10^{-7}(T_e/300)^{-0.85}$	(53)
e^-	+	NO^+	→	O	+	N(2D)	$3.36\times 10^{-7}(T_e/300)^{-0.85}$	(53)
e^-	+	N_2O^+	→	O	+	N_2	$2.70\times 10^{-7}(T_e/300)^{-0.50}$	(53)
e^-	+	NO_2^+	→	O	+	NO	$2.70\times 10^{-7}(T_e/300)^{-0.50}$	(53)
e^-	+	$O_2^+N_2$	→	O_2	+	N_2	$1.30\times 10^{-6}(T_e/300)^{-0.50}$	(53)
e^-	+	N_3^+	→	N	+	N_2	$2.00\times 10^{-7}(T_e/300)^{-0.50}$	(53)
e^-	+	N_4^+	→	N_2	+	N_2	$2.00\times 10^{-6}(T_e/300)^{-0.53}$	(53)
e^-	+	N_4^+	→	N_2	+	2N	$1.40\times 10^{-6}(T_e/300)^{-0.41}$	(54)
e^-	+	N_3^+	→	N	+	$N_2(A^3\Sigma_u^+)$	$4.30\times 10^{-7}(T_e/300)^{-0.50}$	(45)
e^-	+	N_3^+	→	N	+	$N_2\left(B^3\Pi_g\right)$	$4.30\times 10^{-7}(T_e/300)^{-0.50}$	(45)
e^-	+	CO_2^+	→	CO	+	O	$2.15\times 10^{-3}{T_e}^{-0.50}/T_g$	(55)
e^-	+	CO_2^+	→	C	+	O_2	$1.66\times 10^{-5}{T_e}^{-0.40}$	(56)
e^-	+	$C_2O_2^+$	→	CO	+	CO	$9.64\times 10^{-6}{T_e}^{-0.34}$	(57)
e^-	+	CO_4^+	→	CO_2	+	O_2	$4.31\times 10^{-5}{T_e}^{-0.50}$	(56)
e^-	+	CO^+	→	C	+	O	$6.33\times 10^{-6}{T_e}^{-0.55}$	(58)
e^-	+	$C_2O_3^+$	→	CO_2	+	CO	$3.78\times 10^{-5}{T_e}^{-0.70}$	(57)
e^-	+	$C_2O_4^+$	→	CO_2	+	CO_2	$2.15\times 10^{-3}{T_e}^{-0.50}/T_g$	(57)
e^-	+	C_2^+	→	C	+	C	$1.93\times 10^{-6}{T_e}^{-0.50}$	(57)

e^-	+	H_3O^+	→	H_2O	+	H			$2.50\times 10^{-8}(T_e/11604.5)^{-0.70}$	(31)
e^-	+	H_3O^+	→	OH	+	H_2			$1.40\times 10^{-8}(T_e/11604.5)^{-0.70}$	(31)
e^-	+	H_3O^+	→	OH	+	2H			$6.00\times 10^{-8}(T_e/11604.5)^{-0.70}$	(31)
e^-	+	H_3O^+	→	O	+	H	+	H_2	$1.30\times 10^{-9}(T_e/11604.5)^{-0.70}$	(31)
e^-	+	H_2O^+	→	OH	+	H			$1.49\times 10^{-6}T_e{}^{-0.50}$	(59)
e^-	+	H_2O^+	→	O	+	H_2			$4.75\times 10^{-7}T_e{}^{-0.50}$	(59)
e^-	+	H_2O^+	→	O	+	2H			$5.28\times 10^{-6}T_e{}^{-0.50}$	(59)
e^-	+	OH^+	→	O	+	H			$6.50\times 10^{-7}T_e{}^{-0.50}$	(52)

Table S3. Neutral-neutral reactions included in the model, as well as the corresponding rate coefficients and the references where these data were adopted from. The units of the rate constants are s^{-1}, cm^3s^{-1} and cm^6s^{-1} for one, two and three body reactions, respectively. Gas constant R = 8.314×10^{-3} kJ $mole^{-1}$ K^{-1}. The rate constants are in cm^3 s^{-1} or cm^6 s^{-1} for binary or ternary reactions, respectively.

$CH_4 + CH_2$	→	$CH_3 + CH_3$	3.01×10^{-19}	(60)
$CH_4 + CH$	→	$C_2H_4 + H$	9.97×10^{-11}	(61)
$CH_4 + C_2H_5$	→	$C_2H_6 + CH_3$	$2.51 \times 10^{-15}(T_g/298)^{4.14}\exp(-52.55/(RT_g))$	(60)
$CH_4 + C_2H_3$	→	$C_2H_4 + CH_3$	$2.13 \times 10^{-14}(T_g/298)^{4.02}\exp(-22.86/(RT_g))$	(60)
$C_2H_4 + CH_3$	→	$CH_4 + C_2H_3$	$6.91 \times 10^{-12}\exp(-6.56/(RT_g))$	(61)
$CH_4 + C_2H$	→	$C_2H_2 + CH_3$	$4.54 \times 10^{-12}(T_g/298)^{1.58}\exp(-1.73/(RT_g))$	(62)
$C_2H_2 + CH_3$	→	$CH_4 + C_2H$	$3.01 \times 10^{-13}\exp(-72.34/(RT_g))$	(60)
$CH_4 + C_3H_7$	→	$C_3H_8 + CH_3$	$3.54 \times 10^{-16}(T_g/298)^{4.02}\exp(-45.48/(RT_g))$	(63)
$C_3H_8 + CH_3$	→	$CH_4 + C_3H_7$	$1.61 \times 10^{-15}(T_g/298)^{3.65}\exp(-29.93/(RT_g))$	(63)
$CH_4 + C_3H_5$	→	$C_3H_6 + CH_3$	$1.71 \times 10^{-14}(T_g/298)^{3.40}\exp(-97.28/(RT_g))$	(64)
$C_3H_6 + CH_3$	→	$CH_4 + C_3H_5$	$1.68 \times 10^{-15}(T_g/298)^{3.50}\exp(-23.78/(RT_g))$	(64)
$CH_4 + H$	→	$CH_3 + H_2$	$2.94 \times 10^{-10}\exp(-57.65/(RT_g))$	(61)
$CH_3 + H_2$	→	$CH_4 + H$	$6.86 \times 10^{-14}(T_g/298)^{2.74}\exp(-39.41/(RT_g))$	(61)
$CH_3 + CH_3$	→	$C_2H_5 + H$	$1.46 \times 10^{-11}(T_g/298)^{0.10}\exp(-44.40/(RT_g))$	(65)
$C_2H_5 + H$	→	$CH_3 + CH_3$	5.99×10^{-11}	(61)
$CH_3 + CH_3 + M$	→	$C_2H_6 + M$	$2.39 \times 10^{-30}\exp(29.52/(RT_g))$	(66)
$CH_3 + CH_2$	→	$C_2H_4 + H$	7.01×10^{-11}	(61)
$CH_3 + C_2H_6$	→	$C_2H_5 + CH_4$	$1.74 \times 10^{-16}(T_g/298)^{6.00}\exp(-25.28/(RT_g))$	(61)
$CH_3 + C_2H_5$	→	$C_2H_4 + CH_4$	$3.30 \times 10^{-11}(T_{gas})^{0.50}$	(61)

$CH_3 + C_2H_5 + M$	→	$C_3H_8 + M$	5.0×10^{-29}	a
$CH_3 + C_2H_4$	→	$C_2H_3 + CH_4$	1.94×10^{-21}	(60)
$CH_3 + C_2H_3$	→	$C_2H_2 + CH_4$	6.51×10^{-13}	(60)
$CH_3 + C_3H_7$	→	$C_3H_6 + CH_4$	$3.07 \times 10^{-12}(T_g/298)^{-0.32}$	(63)
$CH_3 + H$	→	$CH_2 + H_2$	$1.00 \times 10^{-10}\exp(-63.19/(RT_g))$	(61)
$CH_2 + H_2$	→	$CH_3 + H$	5.00×10^{-15}	(60)
$CH_3 + H + M$	→	$CH_4 + M$	$3.01 \times 10^{-28}(T_g/298)^{-1.80}$	(61)
$CH_2 + CH_2$	→	$C_2H_2 + 2H$	$3.32 \times 10^{-10}\exp(-45.98/(RT_g))$	(61)
$CH_2 + C_2H_5$	→	$C_2H_4 + CH_3$	3.01×10^{-11}	(60)
$CH_2 + C_2H_3$	→	$C_2H_2 + CH_3$	3.01×10^{-11}	(60)
$CH_2 + C_2H$	→	$C_2H_2 + CH$	3.01×10^{-11}	(60)
$CH_2 + C_3H_8$	→	$C_3H_7 + CH_3$	$1.61 \times 10^{-15}(T_g/298)^{3.65}\exp(-29.93/(RT_g))$	(63)
$CH_2 + C_3H_7$	→	$C_2H_4 + C_2H_5$	3.01×10^{-11}	(63)
$CH_2 + C_3H_7$	→	$C_3H_6 + CH_3$	3.01×10^{-12}	(63)
$CH_2 + C_3H_6$	→	$C_3H_5 + CH_3$	$1.20 \times 10^{-12}\exp(-25.94/(RT_g))$	(64)
$CH_2 + H$	→	$CH + H_2$	$1.00 \times 10^{-11}\exp(7.48/(RT_g))$	(61)
$CH + H_2$	→	$CH_2 + H$	$1.48 \times 10^{-11}(T_g/298)^{1.79}\exp(-6.98/(RT_g))$	(61)
$CH + C_2H_6 + M$	→	$C_3H_7 + M$	1.14×10^{-29}	(61)
$CH + H$	→	$C + H_2$	$1.31 \times 10^{-10}\exp(-6.70/(RT_g))$	(67)
$C + H_2$	→	$CH + H$	1.50×10^{-10}	(68)
$C_2H_6 + C_2H_3$	→	$C_2H_5 + C_2H_4$	$1.46 \times 10^{-13}(T_g/298)^{3.30}\exp(-43.9/(RT_g))$	(61)
$C_2H_5 + C_2H_4$	→	$C_2H_6 + C_2H_3$	$5.83 \times 10^{-14}(T_g/298)^{3.13}\exp(-75.33/(RT_g))$	(61)
$C_2H_6 + C_2H$	→	$C_2H_2 + C_2H_5$	5.99×10^{-12}	(61)

$C_2H_2 + C_2H_5$	→	$C_2H_6 + C_2H$	$4.50 \times 10^{-13} \exp(-98.11/(RT_g))$	(61)
$C_2H_6 + C_3H_7$	→	$C_3H_8 + C_2H_5$	$1.19 \times 10^{-15}(T_g/298)^{3.82} \exp(-37.83/(RT_g))$	(63)
$C_3H_8 + C_2H_5$	→	$C_2H_6 + C_3H_7$	$1.61 \times 10^{-15}(T_g/298)^{3.65} \exp(-38.25/(RT_g))$	(63)
$C_2H_6 + C_3H_5$	→	$C_3H_6 + C_2H_5$	$5.71 \times 10^{-14}(T_g/298)^{3.30} \exp(-83.06/(RT_g))$	(64)
$C_3H_6 + C_2H_5$	→	$C_2H_6 + C_3H_5$	$1.69 \times 10^{-15}(T_g/298)^{3.50} \exp(-27.77/(RT_g))$	(64)
$C_2H_6 + H$	→	$C_2H_5 + H_2$	$1.23 \times 10^{-11}(T_g/298)^{1.50} \exp(-31.01/(RT_g))$	(61)
$C_2H_5 + H_2$	→	$C_2H_6 + H$	$4.12 \times 10^{-15}(T_g/298)^{3.60} \exp(-35.34/(RT_g))$	(61)
$C_2H_5 + C_2H_5$	→	$C_2H_6 + C_2H_4$	2.41×10^{-12}	(61)
$C_2H_5 + C_2H$	→	$C_2H_4 + C_2H_2$	3.01×10^{-12}	(60)
$C_2H_5 + C_3H_7$	→	$C_3H_8 + C_2H_4$	1.91×10^{-12}	(63)
$C_2H_5 + C_3H_7$	→	$C_3H_6 + C_2H_6$	2.41×10^{-12}	(63)
$C_2H_5 + C_3H_5$	→	$C_3H_6 + C_2H_4$	$4.30 \times 10^{-12} \exp(0.55/(RT_g))$	(64)
$C_2H_5 + H$	→	$C_2H_4 + H_2$	3.01×10^{-12}	(60)
$C_2H_5 + H$	→	C_2H_6	5.99×10^{-11}	(69)
$C_2H_4 + C_2H$	→	$C_2H_2 + C_2H_3$	1.40×10^{-10}	(70)
$CH_3 + C_2H_3 + M$	→	$C_3H_6 + M$	4.91×10^{-30}	(70)
$C_2H_4 + H$	→	$C_2H_3 + H_2$	$4.0 \times 10^{-12}(T_g/298)^{2.53} \exp(-51.22/(RT_g))$	(60)
$C_2H_3 + H_2$	→	$C_2H_4 + H$	$1.61 \times 10^{-13}(T_g/298)^{2.63} \exp(-35.75/(RT_g))$	(60)
$C_2H_4 + H$	→	$C_2H_5 + M$	$7.69 \times 10^{-30} \exp(-3.16/(RT_g))$	(71)
$C_2H_3 + C_2H_3$	→	$C_2H_4 + C_2H_2$	1.60×10^{-12}	(60)
$C_2H_3 + C_2H$	→	$C_2H_2 + C_2H_2$	1.60×10^{-12}	(60)
$C_2H_3 + C_3H_8$	→	$C_2H_4 + C_3H_7$	$1.46 \times 10^{-13}(T_g/298)^{3.30} \exp(-43.9/(RT_g))$	(63)
$C_2H_3 + C_3H_7$	→	$C_3H_8 + C_2H_2$	2.01×10^{-12}	(63)

$C_2H_3 + C_3H_7$	→	$C_3H_6 + C_2H_4$	2.01×10^{-12}	(63)
$C_2H_3 + C_3H_6$	→	$C_3H_5 + C_2H_4$	$1.68 \times 10^{-15}(T_g/298)^{3.50}\exp(-19.62/(RT_g))$	(64)
$C_2H_3 + C_3H_5$	→	$C_3H_6 + C_2H_2$	8.00×10^{-12}	(64)
$C_2H_3 + H$	→	$C_2H_2 + H_2$	2.01×10^{-11}	(61)
$C_2H_3 + H + M$	→	$C_2H_4 + M$	8.26×10^{-30}	(72)
$C_2H_2 + H$	→	$C_2H + H_2$	$1.00 \times 10^{-10}\exp(-93.12/(RT_g))$	(60)
$C_2H + H_2$	→	$C_2H_2 + H$	$2.51 \times 10^{-11}\exp(-12.97/(RT_g))$	(61)
$C_2H_2 + H + M$	→	$C_2H_3 + M$	$1.08 \times 10^{-25}(T_g/298)^{-7.27}\exp(-30.18/(RT_g))$	(61)
$C_2H + C_2H$	→	$C_2H_2 + C_2$	3.01×10^{-12}	(60)
$C_2H + C_3H_8$	→	$C_2H_2 + C_3H_7$	5.99×10^{-12}	(63)
$C_2H + C_3H_7$	→	$C_3H_6 + C_2H_2$	1.00×10^{-11}	(63)
$C_2H + C_3H_6$	→	$C_3H_5 + C_2H_2$	5.99×10^{-12}	(64)
$C_2H + H + M$	→	$C_2H_2 + M$	9.44×10^{-30}	(72)
$C_3H_8 + C_3H_5$	→	$C_3H_6 + C_3H_7$	$5.71 \times 10^{-14}(T_g/298)^{3.30}\exp(-83.06/(RT_g))$	(64)
$C_3H_6 + C_3H_7$	→	$C_3H_8 + C_3H_5$	$1.69 \times 10^{-15}(T_g/298)^{3.50}\exp(-27.77/(RT_g))$	(64)
$C_3H_8 + H$	→	$C_3H_7 + H_2$	$4.23 \times 10^{-12}(T_g/298)^{2.54}\exp(-28.27/(RT_g))$	(63)
$C_3H_7 + H_2$	→	$C_3H_8 + H$	$3.19 \times 10^{-14}(T_g/298)^{2.84}\exp(-38.25/(RT_g))$	(63)
$C_3H_7 + C_3H_7$	→	$C_3H_6 + C_3H_8$	2.81×10^{-12}	(63)
$C_3H_7 + C_3H_5$	→	$C_3H_6 + C_3H_6$	$2.41 \times 10^{-12}\exp(0.55/(RT_g))$	(64)
$C_3H_7 + H$	→	$C_3H_6 + H_2$	3.01×10^{-12}	(63)
$C_3H_7 + H$	→	C_3H_8	$9.67 \times 10^{-11}(T_g/298)^{0.22}$	(9)(72)
$C_3H_6 + H$	→	$C_3H_5 + H_2$	$4.40 \times 10^{-13}(T_g/298)^{2.50}\exp(-10.39/(RT_g))$	(64)
$C_3H_5 + H_2$	→	$C_3H_6 + H$	$1.39 \times 10^{-13}(T_g/298)^{2.38}\exp(-79.49/(RT_g))$	(64)

$C_3H_6 + H + M$	→	$C_3H_7 + M$	3.79×10^{-33}	(64)
$C_3H_5 + H + M$	→	$C_3H_6 + M$	1.33×10^{-29}	(73)
$H + H_2$	→	3H	$4.67 \times 10^{-07}(T_g/298)^{-1.00}\exp(-55000.0/T_{gas})$	(59)
$H + H + M$	→	$H_2 + M$	$6.04 \times 10^{-33}(T_g/298)^{-1.00}$	(61)
$H_2(E) + H_2$	→	$2H_2$	1.00×10^{-13}	(31)
$H(^2P) + H_2$	→	$H + H_2$	1.00×10^{-13}	(31)
$CH_4 + O$	→	$CH_3 + OH$	$8.32 \times 10^{-12}(T_g/298)^{1.56}\exp(-35.503/(RT_g))$	(61)
$CH_3 + OH$	→	$CH_4 + O$	$3.22 \times 10^{-14}(T_g/298)^{2.20}\exp(-18.62/(RT_g))$	(74)
$CH_3 + O$	→	$CH_2O + H$	1.12×10^{-10}	(75)
$CH_3 + O$	→	$CO + H_2 + H$	2.80×10^{-11}	(75)
$CH_3 + O_2 + M$	→	$CH_3O_2 + M$	$2.19 \times 10^{-12}(T_g/298)^{0.90}$	(76)
$CH_3 + O_3$	→	$CH_3O + O_2$	9.79×10^{-31}	(77)
$CH_2 + O$	→	$CO + H_2$	5.53×10^{-11}	(75)
$CH_2 + O$	→	$CO + 2H$	8.29×10^{-11}	(75)
$CH_2 + O_2$	→	$CO_2 + H_2$	$2.99 \times 10^{-11}(T_g/298)^{-3.30}\exp(-11.97/(RT_g))$	(78)
$CH_2 + O_2$	→	$CO + H_2O$	1.42×10^{-12}	(78)
$CH_2 + O_2$	→	$CH_2O + O$	5.39×10^{-13}	(78)
$CH + O$	→	$CO + H$	6.59×10^{-11}	(61)
$CH + O_2$	→	$CO_2 + H$	1.20×10^{-11}	(75)
$CH + O_2$	→	$CO + OH$	8.00×10^{-12}	(75)
$CH + O_2$	→	$CHO + O$	8.00×10^{-12}	(75)
$CH + O_2$	→	$CO + H + O$	1.20×10^{-11}	(75)
$C + O_2$	→	$CO + O$	4.70×10^{-11}	(79)
$C_2H_6 + O$	→	$C_2H_5 + OH$	$8.54 \times 10^{-12}(T_g/298)^{1.50}\exp(-24.28/(RT_g))$	(61)

$C_2H_5 + OH$	→	$C_2H_6 + O$	$9.85 \times 10^{-19}(T_g/298)^{8.80}\exp(-2.08/(RT_g))$	(60)
$C_2H_5 + O$	→	$CH_3CHO + H$	8.80×10^{-11}	(75)
$C_2H_5 + O$	→	$CH_2O + CH_3$	6.90×10^{-11}	(75)
$C_2H_5 + O$	→	$C_2H_4 + OH$	$6.31 \times 10^{-12}\left(\frac{T_{gas}}{298}\right)^{0.03}\exp(1.65/(RT_g))$	(75)
$C_2H_5 + O_2$	→	$C_2H_4 + HO_2$	3.80×10^{-15}	(77)
$C_2H_5 + O_2$	→	$C_2H_5O_2$	$3.98 \times 10^{-12}(T_g/298)^{-0.44}$	(80)
$C_2H_4 + O$	→	$CH_2CHO + H$	2.63×10^{-13}	(75)
$C_2H_4 + O$	→	$CHO + CH_3$	4.51×10^{-13}	(75)
$C_2H_4 + O_3$	→	$CH_2O + CO_2 + H_2$	7.06×10^{-19}	(77-78)
$C_2H_4 + O_3$	→	$CH_2O + CO + H_2O$	7.06×10^{-19}	(77-78)
$C_2H_4 + O_3$	→	$2CH_2O + O$	2.69×10^{-19}	(77-78)
$C_2H_3 + O$	→	$C_2H_2 + OH$	$5.50 \times 10^{-12}(T_g/298)^{0.20}\exp(1.79/(RT_g))$	(75)
$C_2H_3 + O$	→	$CO + CH_3$	1.25×10^{-11}	(75)
$C_2H_3 + O$	→	$CHO + CH_2$	1.25×10^{-11}	(75)
$C_2H_3 + O$	→	$CH_2CO + H$	1.60×10^{-10}	(75)
$C_2H_3 + O_2$	→	$CH_2O + CHO$	9.00×10^{-12}	(61)
$C_2H_2 + O$	→	$CH_2 + CO$	$3.49 \times 10^{-12}(T_g/298)^{1.50}\exp(-7.07/(RT_g))$	(61)
$C_2H_2 + O$	→	$C_2HO + H$	$7.14 \times 10^{-10}\exp(-50.72/(RT_g))$	(61)
$C_2H + O$	→	$CH + CO$	1.69×10^{-11}	(61)
$C_2H + O_2$	→	$CHO + CO$	3.00×10^{-11}	(61)
$C_2H + O_2$	→	$C_2HO + O$	1.00×10^{-12}	(60)
$C_3H_8 + O$	→	$C_3H_7 + OH$	$1.37 \times 10^{-12}(T_g/298)^{2.68}\exp(-15.548/(RT_g))$	(63)
$H_2 + O$	→	$OH + H$	$2.21 \times 10^{-12}(T_g/298)^{2.00}\exp(-31.595/(RT_g))$	(81)

$H + OH + M$	→	$H_2 + O + M$	$4.38 \times 10^{-33}(T_g/298)^{-2.00}$	(61)
$H + O + M$	→	$OH + M$	$4.36 \times 10^{-32}(T_g/298)^{-1.00}$	(60)
$OH + M$	→	$H + O + M$	$4.00 \times 10^{-09}\exp(-416.0/(RT_g))$	(60)
$H + O_2$	→	$OH + O$	$1.62 \times 10^{-10}\text{xp}(-62.109/(RT_g))$	(71)
$OH + O$	→	$H + O_2$	$4.55 \times 10^{-12}(T_g/298)^{0.40}\exp(-3.097/(RT_g))$	(82)
$H + O_2 + M$	→	$HO_2 + M$	$6.09 \times 10^{-32}(T_g/298)^{-0.80}$	(71)
$H + O_3$	→	$OH + O_2$	2.83×10^{-11}	(83)
$CH_4 + OH$	→	$CH_3 + H_2O$	$1.36 \times 10^{-13}(T_g/298)^{3.04}\exp(-7.649/(RT_g))$	(84)
$CH_3 + H_2O$	→	$CH_4 + OH$	$1.20 \times 10^{-14}(T_g/298)^{2.90}\exp(-62.19/(RT_g))$	(60)
$CH_4 + HO_2$	→	$CH_3 + H_2O_2$	$3.01 \times 10^{-13}\exp(-77.74/(RT_g))$	(60)
$CH_3 + H_2O_2$	→	$CH_4 + HO_2$	$2.01 \times 10^{-14}\exp(2.49/(RT_g))$	(60)
$CH_4 + CHO$	→	$CH_3 + CH_2O$	$1.36 \times 10^{-13}(T_g/298)^{2.85}\exp(-93.954/(RT_g))$	(60)
$CH_3 + CH_2O$	→	$CH_4 + CHO$	$1.60 \times 10^{-16}(T_g/298)^{6.10}\exp(-8.23/(RT_g))$	(71)
$CH_4 + CH_3O$	→	$CH_3OH + CH_3$	$2.61 \times 10^{-13}\exp(-37.0/(RT_g))$	(60)
$CH_3OH + CH_3$	→	$CH_4 + CH_3O$	$1.12 \times 10^{-15}(T_g/298)^{3.10}\exp(-29.02/(RT_g))$	(85)
$CH_4 + CH_3O_2$	→	$CH_3 + CH_3OOH$	$3.01 \times 10^{-13}\exp(-77.32/(RT_g))$	(60)
$CH_3 + CO + M$	→	$CH_3CO + M$	$7.83 \times 10^{-29}(T_g/298)^{-7.56}\exp(-45.65/(RT_g))$	(71)
CH_3CO	→	$CH_3 + CO$	$3.87 \times 10^{13}(T_g/298)^{0.63}\exp(-70.70/(RT_g))$	(71)
$CH_3 + OH$	→	$CH_2 + H_2O$	$1.20 \times 10^{-10}\exp(-11.64/(RT_g))$	(71)
$CH_2 + H_2O$	→	$CH_3 + OH$	1.60×10^{-16}	(60)
$CH_3 + OH$	→	$CH_2OH + H$	$1.54 \times 10^{-09}(T_g/298)^{-1.80}\exp(-33.76/(RT_g))$	(86)
$CH_2OH + H$	→	$CH_3 + OH$	1.60×10^{-10}	(85)

CH_3 + OH	→	CH_3O + H	$2.57 \times 10^{-12}(T_g/298)^{-0.23}\exp(-58.28/(RT_g))$	(86)
CH_3O + H	→	CH_3 + OH	9.93×10^{-12}	(75)
CH_3 + OH + M	→	CH_3OH + M	$3.69 \times 10^{-27}\exp(-10.643/(RT_g))$	(87)
CH_3 + HO_2	→	CH_3O + OH	$7.68 \times 10^{-12}(T_g/298)^{0.27}\exp(2.88/(RT_g))$	(61)
CH_3 + HO_2	→	CH_4 + O_2	5.99×10^{-12}	(60)
CH_3 + CHO	→	CH_4 + CO	2.01×10^{-10}	(60)
CH_3 + CH_3O	→	CH_4 + CH_2O	4.00×10^{-11}	(60)
CH_3 + CH_3CHO	→	CH_4 + CH_3CO	$2.97 \times 10^{-16}(T_g/298)^{5.64}\exp(-10.31/(RT_g))$	(61)
CH_4 + CH_3CO	→	CH_3 + CH_3CHO	$4.82 \times 10^{-14}(T_g/298)^{2.88}\exp(-89.8/(RT_g))$	(60)
CH_3 + CH_3O_2	→	$2CH_3O$	4.00×10^{-11}	(60)
CH_2 + CO_2	→	CH_2O + CO	3.90×10^{-14}	(60)
CH_2 + OH	→	CH_2O + H	3.01×10^{-11}	(60)
CH_2 + HO_2	→	CH_2O + OH	3.00×10^{-11}	(60)
CH_2 + CH_2O	→	CH_3 + CHO	1.00×10^{-14}	(60)
CH_2 + CHO	→	CH_3 + CO	3.01×10^{-11}	(60)
CH_2 + CH_3O	→	CH_3 + CH_2O	3.01×10^{-11}	(60)
CH_2 + CH_3O_2	→	CH_2O + CH_3O	3.01×10^{-11}	(60)
CH + CO_2	→	CHO + CO	9.68×10^{-13}	(75)
CH + CO_2	→	2CO + H	9.68×10^{-13}	(75)
CH + CO + M	→	C_2HO + M	$4.15 \times 10^{-30}(T_g/298)^{-1.90}$	(75)
C_2H_6 + OH	→	C_2H_5 + H_2O	$1.06 \times 10^{-12}(T_g/298)^{2.00}\exp(-3.617/(RT_g))$	(61)
C_2H_5 + H_2O	→	C_2H_6 + OH	$2.06 \times 10^{-14}(T_g/298)^{1.44}\exp(-84.81/(RT_g))$	(60)
C_2H_6 + HO_2	→	C_2H_5 + H_2O_2	$4.90 \times 10^{-13}\exp(-65.52/(RT_g))$	(60)
C_2H_5 + H_2O_2	→	C_2H_6 + HO_2	$1.45 \times 10^{-14}\exp(-4.07/(RT_g))$	(60)

$C_2H_6 + CHO$	$\rightarrow$	$C_2H_5 + CH_2O$	$4.18 \times 10^{-13}(T_g/298)^{2.72}\exp(-76.33/(RT_g))$	(60)
$C_2H_5 + CH_2O$	$\rightarrow$	$C_2H_6 + CHO$	$8.19 \times 10^{-14}(T_g/298)^{2.81}\exp(-24.53/(RT_g))$	(60)
$C_2H_6 + CH_3O$	$\rightarrow$	$C_2H_5 + CH_3OH$	$4.00 \times 10^{-13}\exp(-29.68/(RT_g))$	(60)
$C_2H_5 + CH_3OH$	$\rightarrow$	$C_2H_6 + CH_3O$	$1.12 \times 10^{-15}(T_g/298)^{3.10}\exp(-37.42/(RT_g))$	(85)
$C_2H_6 + CH_3O_2$	$\rightarrow$	$C_2H_5 + CH_3OOH$	$4.90 \times 10^{-13}\exp(-62.52/(RT_g))$	(60)
$C_2H_6 + C_2H_5O_2$	$\rightarrow$	$C_2H_5 + C_2H_5OOH$	$2.87 \times 10^{-14}(T_g/298)^{3.76}\exp(-71.96/(RT_g))$	(88)
$C_2H_5 + OH$	$\rightarrow$	$C_2H_4 + H_2O$	4.00×10^{-11}	(60)
$C_2H_5 + HO_2$	$\rightarrow$	$C_2H_6 + O_2$	5.00×10^{-13}	(60)
$C_2H_5 + HO_2$	$\rightarrow$	$C_2H_4 + H_2O_2$	5.00×10^{-13}	(60)
$C_2H_5 + CHO$	$\rightarrow$	$C_2H_6 + CO$	2.01×10^{-10}	(60)
$C_2H_5 + CH_3O$	$\rightarrow$	$C_2H_6 + CH_2O$	4.00×10^{-11}	(60)
$C_2H_5 + CH_3O_2$	$\rightarrow$	$CH_3O + C_2H_5O$	4.00×10^{-11}	(60)
$C_2H_4 + OH$	$\rightarrow$	$C_2H_3 + H_2O$	$1.66 \times 10^{-13}(T_g/298)^{2.75}\exp(-17.46/(RT_g))$	(60)
$C_2H_3 + H_2O$	$\rightarrow$	$C_2H_4 + OH$	$1.20 \times 10^{-14}(T_g/298)^{2.90}\exp(-62.19/(RT_g))$	(60)
$C_2H_4 + HO_2$	$\rightarrow$	$CH_3CHO + OH$	$1.00 \times 10^{-14}\exp(-33.26/(RT_g))$	(60)
$C_2H_3 + OH$	$\rightarrow$	$C_2H_2 + H_2O$	5.00×10^{-11}	(60)
$C_2H_3 + CH_2O$	$\rightarrow$	$C_2H_4 + CHO$	$8.07 \times 10^{-14}(T_g/298)^{2.81}\exp(-24.53/(RT_g))$	(60)
$C_2H_3 + CHO$	$\rightarrow$	$C_2H_4 + CO$	1.50×10^{-10}	(60)
$C_2H_3 + CH_3O$	$\rightarrow$	$C_2H_4 + CH_2O$	4.00×10^{-11}	(60)
$C_2H_2 + OH$	$\rightarrow$	$C_2H + H_2O$	$5.00 \times 10^{-12}(T_g/298)^{2.00}\exp(-58.53/(RT_g))$	(60)
$C_2H_2 + HO_2$	$\rightarrow$	$CH_2CO + OH$	$1.00 \times 10^{-14}\exp(-33.26/(RT_g))$	(60)
$C_2H + OH$	$\rightarrow$	$CH_2 + CO$	3.01×10^{-11}	(60)
$C_2H + OH$	$\rightarrow$	$C_2H_2 + O$	3.01×10^{-11}	(60)

$C_2H + HO_2$	→	$C_2H_2 + O_2$	3.01×10^{-11}	(60)
$C_2H + HO_2$	→	$C_2HO + OH$	3.01×10^{-11}	(60)
$C_2H + CHO$	→	$C_2H_2 + CO$	1.00×10^{-10}	(60)
$C_2H + CH_3O$	→	$C_2H_2 + CH_2O$	4.00×10^{-11}	(60)
$C_2H + CH_3O_2$	→	$CH_3O + C_2HO$	4.00×10^{-11}	(60)
$C_3H_8 + OH$	→	$C_3H_7 + H_2O$	$1.44 \times 10^{-12}\left(T_g/298\right)^{1.00}\exp(-1.08/(RT_g))$	(63)
$C_3H_8 + HO_2$	→	$C_3H_7 + H_2O_2$	$1.61 \times 10^{-13}\left(T_g/298\right)^{2.55}\exp(-69.01/(RT_g))$	(63)
$C_3H_7 + H_2O_2$	→	$C_3H_8 + HO_2$	$5.15 \times 10^{-15}\left(T_g/298\right)^{2.11}\exp(-10.73/(RT_g))$	(63)
$C_3H_8 + CHO$	→	$C_3H_7 + CH_2O$	$5.21 \times 10^{-13}\left(T_g/298\right)^{2.50}\exp(-77.16/(RT_g))$	(63)
$C_3H_7 + CH_2O$	→	$C_3H_8 + CHO$	$7.49 \times 10^{-14}\left(T_g/298\right)^{2.90}\exp(-24.53/(RT_g))$	(63)
$C_3H_8 + CH_3O$	→	$C_3H_7 + CH_3OH$	$7.21 \times 10^{-13}\exp(-27.02/(RT_g))$	(63)
$C_3H_7 + CH_3OH$	→	$C_3H_8 + CH_3O$	$1.12 \times 10^{-15}\left(T_g/298\right)^{3.10}\exp(-37.42/(RT_g))$	(63)
$C_3H_8 + CH_3O_2$	→	$C_3H_7 + CH_3OOH$	$1.00 \times 10^{-11}\exp(-81.07/(RT_g))$	(63)
$C_3H_7 + CHO$	→	$C_3H_8 + CO$	1.00×10^{-10}	(63)
$C_3H_7 + CH_3O$	→	$C_3H_8 + CH_2O$	4.00×10^{-11}	(63)
$C_3H_7 + CH_3O_2$	→	$C_2H_5 + CH_2O + CH_3O$	5.99×10^{-11}	(63)
$H_2 + OH$	→	$H + H_2O$	$1.05 \times 10^{-10}\exp(-24.694/(RT_g))$	(89)
$H + H_2O$	→	$H_2 + OH$	$6.82 \times 10^{-12}\left(T_g/298\right)^{1.60}\exp(-80.82/(RT_g))$	(61)
$H_2 + HO_2$	→	$H + H_2O_2$	$5.00 \times 10^{-11}\exp(-109.0/(RT_g))$	(60)
$H + H_2O_2$	→	$H_2 + HO_2$	$2.81 \times 10^{-12}\exp(-15.71/(RT_g))$	(61)
$H_2 + CHO$	→	$H + CH_2O$	$2.66 \times 10^{-13}\left(T_g/298\right)^{2.00}\exp(-74.58/(RT_g))$	(60)
$H + CH_2O$	→	$H_2 + CHO$	$2.14 \times 10^{-12}\left(T_g/298\right)^{1.62}\exp(-9.06/(RT_g))$	(71)

$H_2 + CH_3O_2$	→	$H + CH_3OOH$	$5.00 \times 10^{-11} \exp(-109.0/(RT_g))$	(60)
$H + CH_3OOH$	→	$H_2 + CH_3O_2$	7.11×10^{-15}	(90)
$H + CO_2$	→	$CO + OH$	$2.51 \times 10^{-10} \exp(-111.0/(RT_g))$	(60)
$CO + OH$	→	$H + CO_2$	$5.40 \times 10^{-14}(T_g/298)^{1.50} \exp(2.08/(RT_g))$	(61)
$H + CO + M$	→	$CHO + M$	$1.99 \times 10^{-33} \exp(-7.0001/(RT_g))$	(81)
$H + OH + M$	→	$H_2O + M$	$4.38 \times 10^{-30}(T_g/298)^{-2.00}$	(61)
$H + HO_2$	→	$H_2 + O_2$	$4.15 \times 10^{-11} \exp(-2.902/(RT_g))$	(91)
$H + HO_2$	→	$H_2O + O$	$8.30 \times 10^{-11} \exp(-4.182/(RT_g))$	(92)
$H + HO_2$	→	$2OH$	$2.81 \times 10^{-10} \exp(-3.66/(RT_g))$	(91)
$H + CHO$	→	$H_2 + CO$	3.32×10^{-10}	(81)
$H + CH_3O$	→	$H_2 + CH_2O$	2.32×10^{-11}	(75)
$H + CH_3CHO$	→	$H_2 + CH_3CO$	8.98×10^{-14}	(61)
$H_2 + CH_3CO$	→	$H + CH_3CHO$	$2.18 \times 10^{-13}(T_g/298)^{1.82} \exp(-73.67/(RT_g))$	(60)
$H + CH_2CO$	→	$CH_3 + CO$	1.04×10^{-13}	(61)
$H + C_2HO$	→	$CH_2 + CO$	2.50×10^{-10}	(61)
$H + CH_3O_2$	→	$OH + CH_3O$	1.60×10^{-10}	(60)
$O + H_2O$	→	$2OH$	$1.38 \times 10^{-10} \exp(-75.745/(RT_g))$	(89)
$2OH$	→	$O + H_2O$	$1.26 \times 10^{-11} \exp(-4.182/(RT_g))$	(89)
$O + HO_2$	→	$O_2 + OH$	$1.36 \times 10^{-11} (T_g/298)^{0.75}$	(93)
$O + CH_2O$	→	$OH + CHO$	$1.78 \times 10^{-11}(T_g/298)^{0.57} \exp(-11.56/(RT_g))$	(61)
$O + CHO$	→	$CO + OH$	5.00×10^{-11}	(61)
$O + CHO$	→	$H + CO_2$	5.00×10^{-11}	(61)
$O + CH_3O$	→	$CH_3 + O_2$	$3.55 \times 10^{-11} \exp(-1.99/(RT_g))$	(94)
$O + CH_3O$	→	$OH + CH_2O$	1.00×10^{-11}	(61)

$O + CH_3CHO$	→	$OH + CH_3CO$	$8.30 \times 10^{-12} \exp(-7.50/(RT_g))$	(61)
$O + CH_2CO$	→	$CH_2 + CO_2$	2.29×10^{-13}	(95)
$O + CH_2CO$	→	$CH_2O + CO$	7.88×10^{-14}	(95)
$O + CH_2CO$	→	$CHO + CO + H$	4.33×10^{-14}	(95)
$O + CH_2CO$	→	$2CHO$	4.33×10^{-14}	(95)
$O + C_2HO$	→	$2CO + H$	1.60×10^{-10}	(61)
$O + CH_3O_2$	→	$CH_3O + O_2$	5.99×10^{-11}	(60)
$O + CH_3OOH$	→	$CH_3O_2 + OH$	5.63×10^{-15}	(75)
$O_2 + CHO$	→	$CO + HO_2$	$8.50 \times 10^{-11} \exp(-7.07/(RT_g))$	(60)
$O_2 + CH_3O$	→	$CH_2O + HO_2$	$4.28 \times 10^{-13} g^{7.60} \exp(14.762/(RT_g))$	(96)
$O_2 + CH_2CHO$	→	$CH_2O + CO + OH$	3.00×10^{-14}	(97-98)
$O_2 + C_2HO$	→	$2CO + OH$	6.46×10^{-13}	(61)
$O_3 + OH$	→	$O_2 + HO_2$	$3.76 \times 10^{-13} (T_g/298)^{1.99} \exp(-5.02/(RT_g))$	(91)
$O_3 + HO_2$	→	$2O_2 + OH$	$1.97 \times 10^{-16} (T_g/298)^{4.57} \exp(5.76/(RT_g))$	(91)
$O_3 + CH_3O_2$	→	$CH_3O + 2O_2$	1.00×10^{-17}	(99)
$CO + HO_2$	→	$CO_2 + OH$	$2.51 \times 10^{-10} \exp(-98.94/(RT_g))$	(61)
$CO + CH_3O$	→	$CO_2 + CH_3$	$2.61 \times 10^{-11} \exp(-49.39/(RT_g))$	(60)
$H_2O + CHO$	→	$CH_2O + OH$	$8.54 \times 10^{-13} (T_g/298)^{1.35} \exp(-109.0/(RT_g))$	(60)
$CH_2O + OH$	→	$H_2O + CHO$	$4.73 \times 10^{-12} (T_g/298)^{1.18} \exp(1.87/(RT_g))$	(77)
$CH_3OH + OH$	→	$H_2O + CH_3O$	$1.66 \times 10^{-11} \exp(-7.10/(RT_g))$	(77)
$2OH + M$	→	$H_2O_2 + M$	$6.04 \times 10^{-31} (T_g/298)^{-3.00}$	(91)
$OH + HO_2$	→	$O_2 + H_2O$	$1.06 \times 10^{-10} (T_g/298)^{-1}$	(100)
$H_2O + CH_3O$	→	$CH_3OH + OH$	$1.46 \times 10^{-15} (T_g/298)^{3.80} \exp(-48.06/(RT_g))$	(101)

$OH + CHO$	→	$CO + H_2O$	1.69×10^{-10}	(61)
$OH + CH_3O$	→	$CH_2O + H_2O$	3.01×10^{-11}	(60)
$OH + CH_3CHO$	→	$CH_3CO + H_2O$	1.49×10^{-11}	(77)
$OH + CH_2CO$	→	$CO + CH_2OH$	1.14×10^{-11}	(102)
$OH + CH_3O_2$	→	$CH_3OH + O_2$	1.00×10^{-10}	(60)
$2HO_2$	→	$H_2O_2 + O_2$	1.63×10^{-12}	(91)
$HO_2 + CH_2O$	→	$CHO + H_2O_2$	$3.30 \times 10^{-12} \exp(-48.81/(RT_g))$	(60)
$CHO + H_2O_2$	→	$HO_2 + CH_2O$	$1.69 \times 10^{-13} \exp(-29.02/(RT_g))$	(60)
$HO_2 + CHO$	→	$OH + H + CO_2$	5.00×10^{-11}	(60)
$HO_2 + CH_3O$	→	$CH_2O + H_2O_2$	5.00×10^{-13}	(60)
$HO_2 + CH_3O_2$	→	$CH_3OOH + O_2$	5.12×10^{-12}	(77)
$HO_2 + C_2H_5O_2$	→	$C_2H_5OOH + O_2$	7.63×10^{-12}	(77)
$CH_2O + CH_3O$	→	$CH_3OH + CHO$	$1.69 \times 10^{-13} \exp(-12.47/(RT_g))$	(60)
$CH_2O + CH_3O_2$	→	$CHO + CH_3OOH$	$3.30 \times 10^{-12} \exp(-48.81/(RT_g))$	(60)
$CHO + CHO$	→	$CH_2O + CO$	5.00×10^{-11}	(61)
$CHO + CH_3O$	→	$CH_3OH + CO$	1.50×10^{-10}	(60)
$CHO + CH_3O_2$	→	$CH_3O + H + CO_2$	5.00×10^{-11}	(60)
$CH_3O + CH_3O$	→	$CH_2O + CH_3OH$	1.00×10^{-10}	(60)
$CH_3O + CH_3O_2$	→	$CH_2O + CH_3OOH$	5.00×10^{-13}	(60)
$CH_3O_2 + CH_3O_2$	→	$CH_3OH + CH_2O + O_2$	2.19×10^{-13}	(77)
$CH_3O_2 + CH_3O_2$	→	$2CH_3O + O_2$	1.29×10^{-13}	(77)
$C_2H_5O_2 + C_2H_5O_2$	→	$C_2H_5OH + CH_3CHO + O_2$	2.43×10^{-14}	(77)
$C_2H_5O_2 + C_2H_5O_2$	→	$2C_2H_5O + O_2$	3.97×10^{-14}	(77)

$CH_4 + CH_2OH$	→	$CH_3OH + CH_3$	$1.68 \times 10^{-15}(T_g/298)^{3.10}\exp(-67.93/(RT_g))$	(85)
$CH_3OH + CH_3$	→	$CH_4 + CH_2OH$	$4.38 \times 10^{-15}(T_g/298)^{3.20}\exp(-30.02/(RT_g))$	(85)
$CH_3 + CH_2OH$	→	$CH_4 + CH_2O$	4.00×10^{-12}	(85)
$CH_3 + C_2H_5OH$	→	$CH_4 + C_2H_5O$	3.11×10^{-19}	(103)
$CH_2 + H_2O_2$	→	$CH_3 + HO_2$	1.00×10^{-14}	(60)
$CH_2 + CH_3CO$	→	$CH_2CO + CH_3$	3.01×10^{-11}	(60)
$CH_2 + CH_3OH$	→	$CH_3O + CH_3$	$1.12 \times 10^{-15}(T_g/298)^{3.10}\exp(-29.02/(RT_g))$	(85)
$CH_2 + CH_3OH$	→	$CH_2OH + CH_3$	$4.38 \times 10^{-15}(T_g/298)^{3.20}\exp(-30.02/(RT_g))$	(85)
$CH_2 + CH_2OH$	→	$CH_2O + CH_3$	2.01×10^{-12}	(85)
$CH_2 + CH_2OH$	→	$C_2H_4 + OH$	4.00×10^{-11}	(85)
$C_2H_6 + CH_3CO$	→	$CH_3CHO + C_2H_5$	$1.91 \times 10^{-13}(T_g/298)^{2.75}\exp(-73.334/(RT_g))$	(60)
$C_2H_6 + CH_2OH$	→	$CH_3OH + C_2H_5$	$8.73 \times 10^{-15}(T_g/298)^{3.00}\exp(-58.451/(RT_g))$	(85)
$CH_3OH + C_2H_5$	→	$C_2H_6 + CH_2OH$	$4.38 \times 10^{-15}(T_g/298)^{3.20}\exp(-38.33/(RT_g))$	(85)
$C_2H_5 + CH_2OH$	→	$C_2H_6 + CH_2O$	4.00×10^{-12}	(85)
$C_2H_5 + CH_2OH$	→	$CH_3OH + C_2H_4$	4.00×10^{-12}	(85)
$C_2H_3 + H_2O_2$	→	$C_2H_4 + HO_2$	$2.01 \times 10^{-14}\exp(2.49/(RT_g))$	(60)
$C_2H_3 + CH_3OH$	→	$C_2H_4 + CH_3O$	$1.12 \times 10^{-15}(T_g/298)^{3.10}\exp(-29.02/(RT_g))$	(85)
$C_2H_3 + CH_3OH$	→	$C_2H_4 + CH_2OH$	$4.38 \times 10^{-15}(T_g/298)^{3.20}\exp(-30.02/(RT_g))$	(85)
$C_2H_3 + CH_2OH$	→	$C_2H_4 + CH_2O$	5.00×10^{-11}	(85)
$C_2H_3 + CH_2OH$	→	$C_3H_5 + OH$	2.01×10^{-11}	(85)
$C_2H_2 + CH_2OH$	→	$C_2H_3 + CH_2O$	$1.20 \times 10^{-12}\exp(-37.66/(RT_g))$	(85)
$C_2H + CH_3OH$	→	$C_2H_2 + CH_3O$	2.01×10^{-12}	(85)
$C_2H + CH_3OH$	→	$C_2H_2 + CH_2OH$	1.00×10^{-11}	(85)

$C_2H + CH_2OH$	→	$C_2H_2 + CH_2O$	5.99×10^{-11}	(85)
$C_3H_8 + CH_3CO$	→	$CH_3CHO + C_3H_7$	$1.89 \times 10^{-13}(T_g/298)^{2.60}\exp(-73.916/(RT_g))$	(63)
$C_3H_8 + CH_2OH$	→	$CH_3OH + C_3H_7$	$6.56 \times 10^{-15}(T_g/298)^{2.95}\exp(-58.451/(RT_g))$	(63)
$CH_3OH + C_3H_7$	→	$C_3H_8 + CH_2OH$	$3.90 \times 10^{-15}(T_g/298)^{3.17}\exp(-38.33/(RT_g))$	(63)
$C_3H_7 + OH$	→	$C_3H_6 + H_2O$	4.00×10^{-11}	(63)
$C_3H_7 + CH_2OH$	→	$C_3H_8 + CH_2O$	1.60×10^{-12}	(63)
$C_3H_7 + CH_2OH$	→	$C_3H_6 + CH_3OH$	8.00×10^{-13}	(63)
$C_3H_6 + O$	→	$C_3H_5 + OH$	$1.56 \times 10^{-11}(T_g/298)^{0.70}\exp(-24.61/(RT_g))$	(64)
$C_3H_6 + OH$	→	$C_3H_5 + H_2O$	$4.60 \times 10^{-13}(T_g/298)^{2.00}\exp(1.25/(RT_g))$	(64)
$C_3H_6 + HO_2$	→	$C_3H_5 + H_2O_2$	$4.33 \times 10^{-14}(T_g/298)^{2.60}\exp(-58.20/(RT_g))$	(64)
$C_3H_5 + H_2O_2$	→	$C_3H_6 + HO_2$	$7.67 \times 10^{-14}(T_g/298)^{2.05}\exp(-56.79/(RT_g))$	(64)
$C_3H_6 + CHO$	→	$C_3H_5 + CH_2O$	$9.05 \times 10^{-13}(T_g/298)^{1.90}\exp(-71.17/(RT_g))$	(64)
$C_3H_5 + CH_2O$	→	$C_3H_6 + CHO$	$1.05 \times 10^{-11}(T_g/298)^{1.90}\exp(-76.08/(RT_g))$	(64)
$C_3H_6 + CH_3O$	→	$C_3H_5 + CH_3OH$	$2.97 \times 10^{-15}(T_g/298)^{2.95}\exp(-50.14/(RT_g))$	(64)
$C_3H_6 + CH_3O_2$	→	$C_3H_5 + CH_3OOH$	$3.30 \times 10^{-12}\exp(-71.34/(RT_g))$	(64)
$C_3H_6 + CH_3CO$	→	$C_3H_5 + CH_3CHO$	$7.82 \times 10^{-13}(T_g/298)^{2.00}\exp(-67.93/(RT_g))$	(64)
$C_3H_5 + CH_3CHO$	→	$C_3H_6 + CH_3CO$	$6.31 \times 10^{-13}\exp(-30.18/(RT_g))$	(64)
$C_3H_6 + CH_2OH$	→	$C_3H_5 + CH_3OH$	$1.99 \times 10^{-15}(T_g/298)^{2.95}\exp(-50.14/(RT_g))$	(64)
$C_3H_5 + CH_3OH$	→	$C_3H_6 + CH_2OH$	$4.33 \times 10^{-14}(T_g/298)^{2.90}\exp(-85.64/(RT_g))$	(64)
$C_3H_5 + HO_2$	→	$C_3H_6 + O_2$	4.40×10^{-12}	(75)
$C_3H_5 + CHO$	→	$C_3H_6 + CO$	1.00×10^{-10}	(64)
$C_3H_5 + CH_3O$	→	$C_3H_6 + CH_2O$	5.00×10^{-11}	(64)

$C_3H_5 + CH_2OH$	→	$C_3H_6 + CH_2O$	3.01×10^{-11}	(64)
$H_2 + CH_2OH$	→	$CH_3OH + H$	$9.96 \times 10^{-14}(T_g/298)^{2.00}\exp(-55.87/(RT_g))$	(85)
$CH_3OH + H$	→	$H_2 + CH_2OH$	$2.42 \times 10^{-12}(T_g/298)^{2.00}\exp(-18.87/(RT_g))$	(85)
$H + H_2O_2$	→	$H_2O + OH$	$1.69 \times 10^{-11}\exp(-14.97/(RT_g))$	(61)
$H + CH_3OH$	→	$CH_3O + H_2$	$6.64 \times 10^{-11}\exp(-25.53/(RT_g))$	(81)
$H + CH_2OH$	→	$CH_2O + H_2$	1.00×10^{-11}	(104)
$H + CH_2OH$	→	CH_3OH	$2.90 \times 10^{-10}(T_g/298)^{0.04}$	(105)
$H + CH_3O$	→	CH_3OH	$1.59 \times 10^{-10}(T_g/298)^{0.24}\exp(26.46/(RT_g))$	(105)
$H + C_2H_5OH$	→	$H_2 + C_2H_5O$	$1.33 \times 10^{-20}(T_g/298)^{10.58}\exp(18.65/(RT_g))$	(106)
$H + CH_3OOH$	→	$H_2O + CH_3O$	5.88×10^{-15}	(90)
$O + H_2O_2$	→	$HO_2 + OH$	$1.42 \times 10^{-12}(T_g/298)^{2.00}\exp(-16.63/(RT_g))$	(75)
$O + H_2O_2$	→	$O_2 + H_2O$	8.91×10^{-16}	(75)
$O + CH_3CO$	→	$OH + CH_2CO$	8.75×10^{-11}	(75)
$O + CH_3CO$	→	$CO_2 + CH_3$	2.63×10^{-10}	(75)
$O + CH_3OH$	→	$OH + CH_2OH$	$7.11 \times 10^{-12}\exp(-8.48/(RT_g))$	(107)
$O + CH_3OH$	→	$OH + CH_3O$	$1.66 \times 10^{-11}\exp(-19.62/(RT_g))$	(108)
$O + CH_2OH$	→	$CH_2O + OH$	7.00×10^{-11}	(85)
$O + C_2H_5OOH$	→	$C_2H_5O_2 + OH$	$3.30 \times 10^{-11}\exp(-19.87/(RT_g))$	(75)
$O_2 + CH_2OH$	→	$CH_2O + HO_2$	$3.77 \times 10^{-15}(T_g/298)^{2.94}\exp(-18.94/(RT_g))$	(109)
$O_2 + C_2H_5O$	→	$CH_3CHO + HO_2$	8.12×10^{-15}	(77)
$OH + H_2O_2$	→	$HO_2 + H_2O$	$1.30 \times 10^{-11}\exp(-5.57/(RT_g))$	(91)
$OH + CH_3CO$	→	$CH_2CO + H_2O$	2.00×10^{-11}	(60)
$OH + CH_3CO$	→	$CH_3 + CO + OH$	5.00×10^{-11}	(60)

$OH + CH_3OH$	→	$H_2O + CH_2OH$	$3.44 \times 10^{-13}(T_g/298)^{2.80}\exp(1.75/(RT_g))$	(101)
$OH + CH_2OH$	→	$CH_2O + H_2O$	4.00×10^{-11}	(85)
$OH + C_2H_5OH$	→	$H_2O + C_2H_5O$	$2.18 \times 10^{-15}(T_g/298)^{3.38}\exp(10.02/(RT_g))$	(77)
$OH + CH_3OOH$	→	$H_2O + CH_3O_2$	$1.79 \times 10^{-12}\exp(1.83/(RT_g))$	(77)
$OH + C_2H_5OOH$	→	$H_2O + C_2H_5O_2$	$1.61 \times 10^{-12}(T_g/298)^{2.32}\exp(6.66/(RT_g))$	(61)
$HO_2 + CH_3CO$	→	$CH_3 + CO_2 + OH$	5.00×10^{-11}	(60)
$HO_2 + CH_3OH$	→	$CH_2OH + H_2O_2$	$1.60 \times 10^{-13}\exp(-52.63/(RT_g))$	(85)
$CH_2OH + H_2O_2$	→	$HO_2 + CH_3OH$	$5.00 \times 10^{-15}\exp(-10.81/(RT_g))$	(85)
$HO_2 + CH_2OH$	→	$CH_2O + H_2O_2$	2.01×10^{-11}	(85)
$CH_2O + CH_3CO$	→	$CH_3CHO + CHO$	$3.01 \times 10^{-13}\exp(-54.04/(RT_g))$	(60)
$CH_2O + CH_2OH$	→	$CH_3OH + CHO$	$7.72 \times 10^{-14}(T_g/298)^{2.80}\exp(-24.53/(RT_g))$	(85)
$CH_3OH + CHO$	→	$CH_2O + CH_2OH$	$2.41 \times 10^{-13}(T_g/298)^{2.90}\exp(-54.88/(RT_g))$	(85)
$CHO + CH_3CO$	→	$CH_3CHO + CO$	1.50×10^{-11}	(60)
$CHO + CH_2OH$	→	$CH_2O + CH_2O$	3.01×10^{-10}	(85)
$CHO + CH_2OH$	→	$CH_3OH + CO$	2.01×10^{-10}	(85)
$CH_3O + CH_3CO$	→	$CH_3OH + CH_2CO$	1.00×10^{-11}	(60)
$CH_3O + CH_3OH$	→	$CH_3OH + CH_2OH$	$5.00 \times 10^{-13}\exp(-17.04/(RT_g))$	(85)
$CH_3OH + CH_2OH$	→	$CH_3O + CH_3OH$	$1.30 \times 10^{-14}\exp(-50.47/(RT_g))$	(85)
$CH_3O + CH_2OH$	→	$CH_2O + CH_3OH$	4.00×10^{-11}	(85)
$CH_3O_2 + H_2O_2$	→	$CH_3OOH + HO_2$	$4.00 \times 10^{-12}\exp(-41.57/(RT_g))$	(60)
$CH_3O_2 + CH_3CO$	→	$CH_3 + CO_2 + CH_3O$	4.00×10^{-11}	(60)
$CH_3O_2 + CH_3OH$	→	$CH_2OH + CH_3OOH$	$3.01 \times 10^{-12}\exp(-57.37/(RT_g))$	(85)

$CH_3O_2 + CH_2OH$	→	$CH_3O + OH + CH_2O$	2.00×10^{-11}	(85)
$H_2O_2 + CH_3CO$	→	$CH_3CHO + HO_2$	$3.01 \times 10^{-13} \exp(-34.42/(RT_g))$	(60)
$CH_3CO + CH_3OH$	→	$CH_3CHO + CH_2OH$	$2.13 \times 10^{-13}(T_g/298)^{3.00}\exp(-51.63/(RT_g))$	(85)
$CH_2OH + CH_2OH$	→	$CH_2O + CH_3OH$	8.00×10^{-12}	(85)
$O + CH_2$	→	$CHO + H$	5.01×10^{-11}	(110)
$C_2H_4 + O$	→	$CH_3 + CHO$	$1.5 \times 10^{-12}(T_g/298)^{1.55}\exp(-1.79/(RT_g))$	(60)
$C_2H_4 + O$	→	$CH_2CHO + H$	$1.13 \times 10^{-12} \exp(-2.93/(RT_g))$	(111)
$CH_3 + O$	→	CH_3O	$1.22 \times 10^{-10}(T_g/298)^{0.05}\exp(0.57/(RT_g))$	(112)
$CO_2 + M$	→	$CO + O + M$	$3.91 \times 10^{-10} \exp(-49430/T_g)$	(113)
$CO_2 + C$	→	$CO + O_2$	$2.80 \times 10^{-11} \exp(-26500/T_g)$	(113)
$CO_2 + C$	→	$2CO$	1.00×10^{-15}	(113)
$CO + O + M$	→	$CO_2 + M$	$8.20 \times 10^{-34} \exp(-1510/T_g)$	(113)
$O_2 + CO$	→	$CO_2 + O$	$4.20 \times 10^{-12} \exp(-2400/T_g)$	(113)
$CO + O_3$	→	$CO_2 + O_2$	4.00×10^{-25}	(113)
$CO + C + M$	→	$C_2O + M$	6.50×10^{-32}	(113)
$C + O + M$	→	$CO + M$	$2.14 \times 10^{-29}(T_g/298)^{-3.08}\exp(-2114/T_g)$	(113)
$O + C_2O$	→	$CO + CO$	5.00×10^{-11}	(113)
$O_2 + C_2O$	→	$CO_2 + CO$	3.30×10^{-13}	(113)
$O_2 + O + M$	→	$O_3 + M$	$8.20 \times 10^{-34} \exp(-1510/T_g)$	(113)
$O + O_3$	→	$O_2 + O_2$	$3.10 \times 10^{-14}(T_g/298)^{0.75}\exp(-1575/T_g)$	(113)
$O_3 + M$	→	$O_2 + O + M$	$1.12 \times 10^{-34} \exp(-11430/T_g)$	(114)
$O + O + M$	→	$O_2 + M$	$1.27 \times 10^{-32}(T_g/298)^{-1.00}\exp(-170/T_g)$	(113)

$O_2 + O_2$	→	$O_3 + O$	$2.10 \times 10^{-11} \exp(-498000/T_g)$	(53)
$N_2(A^3\Sigma_u^+) + O$	→	$NO + N(2D)$	7.00×10^{-12}	(53)
$N_2(A^3\Sigma_u^+) + O$	→	$N_2 + O(1S)$	2.10×10^{-11}	(53)
$N_2(A^3\Sigma_u^+) + O_2$	→	$N_2 + O + O(1D)$	$2.10 \times 10^{-12} (T_g/300)^{0.55}$	(53)
$N_2(A^3\Sigma_u^+) + O_2$	→	$N_2 + O_2$	2.54×10^{-12}	(53)
$N_2(C^3\Pi_u) + O_2$	→	$N_2 + O + O(1S)$	3.00×10^{-10}	(53)
$N_2(A^3\Sigma_u^+) + O_2$	→	$N_2O + O$	$2.00 \times 10^{-14} (T_g/300)^{0.55}$	(53)
$N_2(A^3\Sigma_u^+) + NO$	→	$N_2 + NO$	6.90×10^{-11}	(53)
$N_2(A^3\Sigma_u^+) + N_2O$	→	$N_2 + N + NO$	1.00×10^{-11}	(53)
$N_2(A^3\Sigma_u^+) + NO_2$	→	$N_2 + O + NO$	1.00×10^{-12}	(53)
$N_2(B^3\Pi_g) + O_2$	→	$N_2 + O + NO$	3.00×10^{-10}	(53)
$N_2(B^3\Pi_g) + NO$	→	$N_2(A^3\Sigma_u^+) + NO$	2.40×10^{-10}	(53)
$N_2(a'\Sigma_u^-) + O_2$	→	$N_2 + O + O$	2.80×10^{-11}	(53)
$N_2(a'\Sigma_u^-) + NO$	→	$N_2 + N + O$	3.60×10^{-10}	(53)
$N + N + O_2$	→	$N_2(A^3\Sigma_u^+) + O_2$	1.70×10^{-33}	(53)
$N + N + O$	→	$N_2(A^3\Sigma_u^+) + O$	1.00×10^{-32}	(53)
$N + N + NO$	→	$N_2(A^3\Sigma_u^+) + NO$	1.70×10^{-33}	(53)
$N + N + O_2$	→	$N_2(B^3\Pi_g) + O_2$	2.40×10^{-33}	(53)
$N + N + O$	→	$N_2(B^3\Pi_g) + O$	1.40×10^{-32}	(53)
$N + N + NO$	→	$N_2(B^3\Pi_g) + NO$	2.40×10^{-33}	(53)
$N(2D) + O$	→	$N + O(1D)$	4.00×10^{-13}	(53)
$N(2D) + O_2$	→	$NO + O$	5.20×10^{-12}	(53)
$N(2D) + NO$	→	$N_2 + O$	1.80×10^{-10}	(53)
$N(2D) + N_2O$	→	$N_2 + NO$	3.50×10^{-12}	(53)

N(2P) + O	→	N + O	1.00×10^{-12}	(53)
N(2P) + O_2	→	NO + O	2.60×10^{-12}	(53)
N(2P) + NO	→	$N_2(A^3\Sigma_u^+)$ + O	3.00×10^{-11}	(53)
O(1D) + O	→	O + O	8.00×10^{-12}	(53)
O(1D) + O_2	→	O + O_2	$6.40 \times 10^{-12} \exp(67/T_g)$	(53)
O(1D) + N_2	→	O + N_2	2.30×10^{-11}	(53)
O(1S) + O	→	O(1D) + O	$5.00 \times 10^{-11} \exp(-300/T_g)$	(53)
O(1S) + N	→	O + N	1.00×10^{-12}	(53)
O(1S) + O_2	→	O(1D) + O_2	$1.30 \times 10^{-12} \exp(-850/T_g)$	(53)
O(1S) + O_2	→	O + O + O	$3.00 \times 10^{-12} \exp(-850/T_g)$	(53)
O(1S) + N_2	→	O + N_2	1.00×10^{-17}	(53)
N + NO	→	O + N_2	$1.80 \times 10^{-11} \left(T_g/300\right)^{0.50}$	(53)
N + O_2	→	O + NO	$3.20 \times 10^{-12}\left(T_g/298\right)^{1.00}\exp(-3150/T_g)$	(53)
N + NO_2	→	O + O + N_2	9.10×10^{-13}	(53)
N + NO_2	→	O + N_2O	3.00×10^{-12}	(53)
N + NO_2	→	O_2 + N_2	7.00×10^{-13}	(53)
N + NO_2	→	NO + NO	2.30×10^{-12}	(53)
O + N_2(g, v)	→	N + NO	$3.10 \times 10^{-10}\exp(-38370/T_g)$	(53)
O + NO	→	N + O_2	$7.50 \times 10^{-12}\left(T_g/300\right)^{1.00}\exp(-19500/T_g)$	(53)
O + NO	→	NO_2	4.20×10^{-18}	(53)
O + N_2O	→	O_2 + N_2	$8.13 \times 10^{-12}\exp(-14000/T_g)$	(53)
O + N_2O	→	2NO	$1.50 \times 10^{-10}\exp(-14090/T_g)$	(53)
O + NO_2	→	NO + O_2	$9.10 \times 10^{-12}\left(T_g/300\right)^{0.18}$	(53)
O + NO_3	→	NO_2 + O_2	1.00×10^{-11}	(53)

$N_2(g, v) + O_2$	→	$O + N_2O$	$2.50 \times 10^{-10}\exp(-50390/T_g)$	(53)
$NO + NO$	→	$N + NO_2$	$3.30 \times 10^{-16}(T_g/300)^{-0.50}\exp(-39200/T_g)$	(53)
$NO + NO$	→	$O + N_2O$	$2.20 \times 10^{-12}\exp(-32100/T_g)$	(53)
$NO + NO$	→	$O_2 + N_2$	$5.10 \times 10^{-13}\exp(-33660/T_g)$	(53)
$NO + O_2$	→	$O + NO_2$	$2.80 \times 10^{-12}\exp(-23400/T_g)$	(53)
$NO + N_2O$	→	$N_2 + NO_2$	$4.60 \times 10^{-10}\exp(-25170/T_g)$	(53)
$NO_2 + NO_2$	→	$NO + NO + O_2$	$3.30 \times 10^{-12}\exp(-13500/T_g)$	(53)
$NO_2 + NO_2$	→	$NO + NO_3$	$4.50 \times 10^{-10}\exp(-18500/T_g)$	(53)
$NO_2 + O_3$	→	$O_2 + NO_3$	$1.20 \times 10^{-13}\exp(-2450/T_g)$	(53)
$NO_2 + NO_3$	→	$NO + O_2 + NO_2$	$2.30 \times 10^{-13}\exp(-1600/T_g)$	(53)
$O_2 + NO_3$	→	$NO_2 + O_3$	$1.50 \times 10^{-12}\exp(-15020/T_g)$	(53)
$NO_3 + NO_3$	→	$O_2 + NO_2 + NO_2$	$4.30 \times 10^{-12}\exp(-3850/T_g)$	(53)
$N_2(g, v) + O_2$	→	$N + N + O_2$	$5.40 \times 10^{-8}(1 - \exp(-3354/T_g))\exp(-113200/T_g)$	(53)
$N_2(g, v) + O$	→	$N + N + O$	$5.40 \times 10^{-8}(1 - \exp(-3354/T_g))\exp(-113200/T_g)$	(53)
$N_2(g, v) + NO$	→	$N + N + NO$	$5.40 \times 10^{-8}(1 - \exp(-3354/T_g))\exp(-113200/T_g)$	(53)
$O_2 + N_2$	→	$O + O + N_2$	$6.10 \times 10^{-9}(1 - \exp(-2240/T_g))\exp(-59380/T_g)$	(53)
$O_2 + O_2$	→	$O + O + O_2$	$3.60 \times 10^{-8}(1 - \exp(-2240/T_g))\exp(-59380/T_g)$	(53)

$O_2 + O$	→	$O + O + O$	$1.28 \times 10^{-7}(1 - \exp(-2240/T_g))\exp(-59380/T_g)$	(53)
$O_2 + N$	→	$O + O + N$	$6.10 \times 10^{-9}(1 - \exp(-2240/T_g))\exp(-59380/T_g)$	(53)
$O_2 + NO$	→	$O + O + NO$	$6.10 \times 10^{-9}(1 - \exp(-2240/T_g))\exp(-59380/T_g)$	(53)
$NO + N_2$	→	$N + O + N_2$	$8.70 \times 10^{-9}\exp(-75994/T_g)$	(53)
$NO + O_2$	→	$N + O + O_2$	$8.70 \times 10^{-9}\exp(-75994/T_g)$	(53)
$NO + O$	→	$N + O + O$	$1.74 \times 10^{-7}\exp(-75994/T_g)$	(53)
$NO + N$	→	$N + O + N$	$1.74 \times 10^{-7}\exp(-75994/T_g)$	(53)
$NO + NO$	→	$N + O + NO$	$1.74 \times 10^{-7}\exp(-75994/T_g)$	(53)
$N_2O + N_2$	→	$N_2 + O + N_2$	$1.20 \times 10^{-8}(T_g/300)^{-1.00}\exp(-29000/T_g)$	(53)
$N_2O + O_2$	→	$N_2 + O + O_2$	$1.20 \times 10^{-8}(T_g/300)^{-1.00}\exp(-29000/T_g)$	(53)
$N_2O + NO$	→	$N_2 + O + NO$	$2.40 \times 10^{-8}(T_g/300)^{-1.00}\exp(-29000/T_g)$	(53)
$N_2O + N_2O$	→	$N_2 + O + N_2O$	$4.80 \times 10^{-8}(T_g/300)^{-1.00}\exp(-29000/T_g)$	(53)
$NO_2 + N_2$	→	$NO + O + N_2$	$6.80 \times 10^{-6}(T_g/300)^{-2.00}\exp(-36180/T_g)$	(53)
$NO_2 + O_2$	→	$NO + O + O_2$	$5.30 \times 10^{-6}(T_g/300)^{-2.00}\exp(-36180/T_g)$	(53)
$NO_2 + NO$	→	$NO + O + NO$	$5.30 \times 10^{-5}(T_g/300)^{-2.00}\exp(-36180/T_g)$	(53)
$NO_2 + NO_2$	→	$NO + O + NO_2$	$5.30 \times 10^{-5}(T_g/300)^{-2.00}\exp(-36180/T_g)$	(53)
$NO_3 + N_2$	→	$NO_2 + O + N_2$	$3.10 \times 10^{-5}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)

$NO_3 + O_2$	→	$NO_2 + O + O_2$	$3.10 \times 10^{-5}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + NO$	→	$NO_2 + O + NO$	$3.10 \times 10^{-5}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + O$	→	$NO_2 + O + O$	$3.10 \times 10^{-4}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + N$	→	$NO_2 + O + N$	$3.10 \times 10^{-4}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + N_2$	→	$NO + O_2 + N_2$	$6.20 \times 10^{-5}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + O_2$	→	$NO + O_2 + O_2$	$6.20 \times 10^{-5}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + NO$	→	$NO + O_2 + NO$	$6.20 \times 10^{-5}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + O$	→	$NO + O_2 + O$	$7.44 \times 10^{-4}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$NO_3 + N$	→	$NO + O_2 + N$	$7.44 \times 10^{-4}(T_g/300)^{-2.00}\exp(-25000/T_g)$	(53)
$N_2O_5 + M$	→	$NO_2 + NO_3 + M$	$1.30 \times 10^{-3}(T_g/300)^{-3.50}\exp(-11000/T_g)$	(53)
$N + N + N_2(g, v)$	→	$N_2 + N_2(g, v)$	$\mathrm{Max}(8.30 \times 10^{-34}\exp(500/T_g), 1.91 \times 10^{-33})$	(53)
$N + N + O_2$	→	$N_2 + O_2$	$1.80 \times 10^{-33}\exp(435/T_g)$	(53)
$N + N + NO$	→	$N_2 + NO$	$1.80 \times 10^{-33}\exp(435/T_g)$	(53)
$N + N + N$	→	$N_2 + N$	$5.40 \times 10^{-33}\exp(435/T_g)$	(53)
$N + N + O$	→	$N_2 + O$	$5.40 \times 10^{-33}\exp(435/T_g)$	(53)
$O + O + N_2(g, v)$	→	$O_2 + N_2(g, v)$	$\mathrm{Max}(2.80 \times 10^{-34}\exp(720/T_g), 1.00 \times 10^{-33}(T_g/300)^{-0.41})$	(53)
$O + O + O_2$	→	$O_2 + O_2$	$4.00 \times 10^{-33}(T_g/300)^{-0.41}$	(53)
$O + O + N$	→	$O_2 + N$	$3.20 \times 10^{-33}(T_g/300)^{-0.41}$	(53)
$O + O + O$	→	$O_2 + O$	$1.44 \times 10^{-32}(T_g/300)^{-0.41}$	(53)
$O + O + NO$	→	$O_2 + NO$	$0.51 \times 10^{-32}(T_g/300)^{-0.41}$	(53)
$O + O_2 + N_2(g, v)$	→	$O_2 + N_2(g, v)$	$\mathrm{Max}(5.80 \times 10^{-34}(T_g/300)^{-2.80}, 5.40 \times$	(53)

			$10^{-34}(T_g/300)^{-1.90}$)	
$O + O_2 + O_2$	→	$O_3 + O_2$	$7.60 \times 10^{-34}(T_g/300)^{-1.90}$	(53)
$O + O_2 + NO$	→	$O_3 + NO$	$7.60 \times 10^{-34}(T_g/300)^{-1.90}$	(53)
$O + O_2 + N$	→	$O_2 + N$	Max($3.90 \times 10^{-33}(T_g/300)^{-1.99}, 1.10 \times 10^{-34}\exp(1060/T_g)$)	(53)
$O + O_2 + O$	→	$O_2 + O$	Max($3.90 \times 10^{-33}(T_g/300)^{-1.99}, 1.10 \times 10^{-34}\exp(1060/T_g)$)	(53)
$O + O_2 + H_2O$	→	$O_3 + H_2O$	$9.90 \times 10^{-34}\exp(510/T_g)$	(53)
$O + N_2$(g, v) + M	→	$N_2O + N_2$(g, v) + M	$3.90 \times 10^{-35}\exp(-10400/T_g)$	(53)
$O + NO + N_2$(g, v)	→	$NO_2 + N_2$(g, v)	$1.20 \times 10^{-31}(T_g/300)^{-1.80}$	(53)
$O + NO + O_2$	→	$NO_2 + O_2$	$0.94 \times 10^{-31}(T_g/300)^{-1.80}$	(53)
$O + NO + NO$	→	$NO_2 + NO$	$0.94 \times 10^{-31}(T_g/300)^{-1.80}$	(53)
$O + NO_2 + N_2$(g, v)	→	$NO_3 + N_2$(g, v)	$8.90 \times 10^{-32}(T_g/300)^{-2.00}$	(53)
$O + NO_2 + O_2$	→	$NO_3 + O_2$	$8.90 \times 10^{-32}(T_g/300)^{-2.00}$	(53)
$O + NO_2 + N$	→	$NO_3 + N$	$1.16 \times 10^{-30}(T_g/300)^{-2.00}$	(53)
$O + NO_2 + O$	→	$NO_3 + O$	$1.16 \times 10^{-30}(T_g/300)^{-2.00}$	(53)
$O + NO_2 + NO$	→	$NO_3 + NO$	$2.14 \times 10^{-31}(T_g/300)^{-2.00}$	(53)
$NO_2 + NO_3 + M$	→	$N_2O_5 + M$	$3.60 \times 10^{-30}(T_g/300)^{-4.10}$	(53)
$CO + NO_2$	→	$CO_2 + NO$	$1.48 \times 10^{-10}\exp(-16967/T_g)$	(45)
$NO + O + CO_2$	→	$CO_2 + NO_2$	$1.13 \times 10^{-25}(T_g)^{-2.16}\exp(-529/T_g)$	(115)
$CN + O$	→	$CO + N$	$3.40 \times 10^{-11}\exp(-210/T_g)$	(57)

$CO + N$	→	$CN + O$	$1.00 \times 10^{12}(T_g)^{-0.50}\exp(-38600/T_g)$	(115)
$CN + NO$	→	$ONCN$	$4.30 \times 10^{-12}(T_g)^{-6.20}\exp(-2455/T_g)$	(115)
$CN + NO_2$	→	$NCO + NO$	$4.00 \times 10^{-11}\exp(186/T_g)$	(115)
$CN + CN + N_2(g, v)$	→	$C_2N_2 + N_2(g, v)$	$9.44 \times 10^{-23}(T_g)^{-2.61}$	(115)
$CN + CN + CO_2$	→	$C_2N_2 + CO_2$	$1.50 \times 10^{-22}(T_g)^{-2.62}$	(115)
$NCO + NO$	→	$N_2O + CO$	$5.61 \times 10^{-12}\exp(196/T_g)$	(115)
$NCO + NO$	→	$N_2 + CO_2$	$7.48 \times 10^{-12}\exp(196/T_g)$	(115)
$NCO + NO$	→	$N_2 + CO + O$	$3.91 \times 10^{-12}\exp(196/T_g)$	(115)
$NCO + NO_2$	→	$CO + 2NO$	3.00×10^{-11}	(115)
$NCO + NO_2$	→	$CO_2 + N_2O$	0.60×10^{-11}	(115)
$NCO + CN$	→	$NCN + CO$	3.00×10^{-11}	(115)
$NCO + NCO$	→	$N_2 + 2CO$	3.00×10^{-11}	(115)
$N_2(B^3\Pi_g)$	→	$N_2(A^3\Sigma_u^+)$	1.34×10^{5}	(53)
$N_2(a'\Sigma_u^-)$	→	N_2	1.00×10^{2}	(53)
$N_2(C^3\Pi_u)$	→	$N_2(B^3\Pi_g)$	2.45×10^{7}	(53)
$N_2(A^3\Sigma_u^+) + N_2$	→	$N_2 + N_2$	3.00×10^{-16}	(53)
$N_2(A^3\Sigma_u^+) + N$	→	$N_2 + N$	2.00×10^{-12}	(53)
$N_2(A^3\Sigma_u^+) + N$	→	$N_2 + N(2P)$	$4.00 \times 10^{-11}(T_g/300)^{-0.667}$	(53)
$N_2(A^3\Sigma_u^+)$ + $N_2(A^3\Sigma_u^+)$	→	$N_2 + N_2(B^3\Pi_g)$	3.00×10^{-10}	(53)
$N_2(A^3\Sigma_u^+) + N_2(A^3\Sigma_u^+)$	→	$N_2 + N_2(C^3\Pi_u)$	1.50×10^{-10}	(53)
$N_2 + N_2(B^3\Pi_g)$	→	$N_2(A^3\Sigma_u^+) + N_2$	3.00×10^{-11}	(53)
$N_2 + N_2(B^3\Pi_g)$	→	$N_2 + N_2$	2.00×10^{-12}	(53)
$N_2(a'\Sigma_u^-) + N_2$	→	$N_2 + N_2(B^3\Pi_g)$	1.90×10^{-13}	(53)

$N_2(C^3\Pi_u) + N_2$	→	$N_2(a'\Sigma_u^-) + N_2$	1.00×10^{-11}	(53)
$N(2D) + N_2$	→	$N + N_2$	$2.30 \times 10^{-14}\exp(-510/T_g)$	(53)
$N(2P) + N$	→	$N + N$	1.80×10^{-12}	(53)
$N(2P) + N$	→	$N(2D) + N$	0.60×10^{-12}	(53)
$N + N + N_2$	→	$N_2 + N_2(B^3\Pi_g)$	2.40×10^{-33}	(53)
$N + N + N_2$	→	$N_2 + N_2(A^3\Sigma_u^+)$	1.70×10^{-33}	(53)
$N(2P) + N_2$	→	$N + N_2$	0.60×10^{-13}	(53)
$N_2(A^3\Sigma_u^+)$	→	N_2	0.50	(53)
$N_2(g, v) + N_2$	→	$N + N + N_2$	$5.40 \times 10^{-8}(1-\exp(-3354/T_g))\exp(-113200/T_g)$	(53)
$N_2(g, v) + N$	→	$N + N + N$	$3.96 \times 10^{-7}(1-\exp(-3354/T_g))\exp(-113200/T_g)$	(53)
$N + O + M$	→	$NO + M$	$1.00 \times 10^{-32}(T_g/300)^{-0.50}$	(53)
$N + O_3$	→	$NO + O_3$	$5.00 \times 10^{-12}\exp(-650/T_g)$	(53)
$NO + NO_2 + M$	→	$N_2O_3 + M$	9.10×10^{-13}	(53)
$N_2O_3 + M$	→	$NO + NO_2 + M$	$1.97 \times 10^{-7}(T_g/300)^{-8.70}\exp(-4880/T_g)$	(53)
$NO_2 + NO_2 + M$	→	$N_2O_4 + M$	$1.40 \times 10^{-33}(T_g/300)^{-3.80}$	(53)
$N_2O_4 + M$	→	$NO_2 + NO_2 + M$	$1.30 \times 10^{-5}(T_g/300)^{-3.80}\exp(-6460/T_g)$	(53)
$CH_4 + CN$	→	$CH_3 + HCN$	$1.00 \times 10^{-11}\exp(-857/T_g)$	(116)
$N + CH_3$	→	$HCN + H_2$	1.40×10^{-11}	(116)
$N + CH_3$	→	$H_2CN + H$	1.18×10^{-10}	(116)
$N + CH_2$	→	$HCN + H$	$5.00 \times 10^{-11}\exp(-250/T_g)$	(116)
$N + CH_2$	→	$CN + 2H$	1.60×10^{-11}	(116)
$N + CH_2$	→	$CN + H_2$	1.60×10^{-11}	(116)

$C + N_2$	→	$CN + N$	$1.04 \times 10^{-10}\exp(-23000/T_g)$	(116)
$N + C_2H_2$	→	$CH + HCN$	2.70×10^{-15}	(117)
$N + C_2H_4$	→	$HCN + CH_3$	$3.30 \times 10^{-14}\exp(-353/T_g)$	(117)
$N + C_3H_6$	→	$HCN + C_2H_5$	$1.94 \times 10^{-13}\exp(-654/T_g)$	(117)
$N + H_2$	→	$NH + H$	$1.69 \times 10^{-9}\exp(-18095/T_g)$	(31)
$N + H_2 + NH_3$	→	$NH_2 + NH_3$	1.00×10^{-36}	(118)
$H_2 + CN$	→	$H + HCN$	$4.98 \times 10^{-19}(T_g)^{2.45}\exp(-1118/T_g)$	(119)
$H + HCN + H_2$	→	$H_2CN + N_2$	$4.84 \times 10^{-30}\exp(-2440/T_g)$	(120)
$H + H + CH_4$	→	$H_2 + CH_4$	6.00×10^{-33}	(61)
$H + H + CO_2$	→	$H_2 + CO_2$	6.00×10^{-33}	(61)
$H + H + O_2$	→	$H_2 + O_2$	6.00×10^{-33}	(61)
$H + H + CO$	→	$H_2 + CO$	6.00×10^{-33}	(61)
$H + H + H_2O$	→	$H_2 + H_2O$	6.00×10^{-33}	(61)
$H + H + H_2$	→	$H_2 + H_2$	$4.00 \times 10^{-32}(T_g/300)^{-1.00}$	(31)
$H + H + N_2$	→	$H_2 + N_2$	$2.00 \times 10^{-32}(T_g/300)^{-1.00}$	(31)
$H + N + CH_4$	→	$NH + CH_4$	5.00×10^{-32}	(31)
$H + N + CO_2$	→	$NH + CO_2$	5.00×10^{-32}	(31)
$H + N + O_2$	→	$NH + O_2$	5.00×10^{-32}	(31)
$H + N + CO$	→	$NH + CO$	5.00×10^{-32}	(31)
$H + N + H_2O$	→	$NH + H_2O$	5.00×10^{-32}	(31)
$H + N + H_2$	→	$NH + H_2$	1.00×10^{-31}	(31)
$H + N + N_2$	→	$NH + N_2$	5.00×10^{-32}	(31)
$H + NH_2$	→	$NH + H_2$	1.00×10^{-11}	(120)
$H + NH_2 + M$	→	$NH_3 + M$	6.00×10^{-30}	(118)

$H + NH$	$\rightarrow$	$N + H_2$	1.70×10^{-11}	(31)
$H_2CN + H$	$\rightarrow$	$HCN + H_2$	$5.02 \times 10^{-10}(T_g/300)^{0.50}$	(120)
$N_2 + CN$	$\rightarrow$	$N_2 + C + N$	$4.15 \times 10^{-10}\exp(-70538/T_g)$	(119)
$N + CH$	$\rightarrow$	$CN + H$	2.10×10^{-11}	(120)
$H_2CN + N$	$\rightarrow$	$HCN + NH$	6.70×10^{-11}	(119)
$N + N + H_2$	$\rightarrow$	$N_2 + H_2$	$2.50 \times 10^{-34}\exp(-500/T_g)$	(31)
$N_2H_4 + N$	$\rightarrow$	$N_2H_2 + NH_2$	1.30×10^{-13}	(118)
$N_2H_4 + H$	$\rightarrow$	$N_2H_3 + H_2$	$1.20 \times 10^{-11}\exp(-1260/T_g)$	(118)
$N_2H_3 + H$	$\rightarrow$	$NH_2 + NH_2$	2.70×10^{-12}	(118)
$N_2H_4 + NH_2$	$\rightarrow$	$NH_3 + N_2H_3$	5.20×10^{-13}	(118)
$N_2H_3 + N_2H_3$	$\rightarrow$	$NH_3 + NH_3 + N_2$	5.00×10^{-12}	(118)
$N_2H_3 + N_2H_3$	$\rightarrow$	$N_2H_4 + N_2H_2$	2.00×10^{-11}	(118)
$NH_3 + H$	$\rightarrow$	$H_2 + NH_2$	$6.50 \times 10^{-13}(T_g/300)^{2.76}\exp(5135/T_g)$	(118)
$N_2H_2 + H$	$\rightarrow$	$N_2 + H_2 + H$	$4.50 \times 10^{-13}(T_g/300)^{2.63}\exp(115/T_g)$	(118)
$N_2H_2 + NH_2$	$\rightarrow$	$N_2 + H + NH_3$	$1.50 \times 10^{-13}(T_g/300)^{4.05}\exp(810/T_g)$	(118)
$NH_3 + NH + NH_3$	$\rightarrow$	$N_2H_4 + NH_3$	1.00×10^{-33}	(118)
$NH_2 + H_2$	$\rightarrow$	$NH_3 + H$	$2.10 \times 10^{-12}\exp(-4277/T_g)$	(118)
$NH_2 + NH$	$\rightarrow$	N_2H_3	1.20×10^{-10}	(118)
$NH_2 + NH_2 + NH_3$	$\rightarrow$	$N_2H_4 + NH_3$	6.90×10^{-30}	(118)
$NH_2 + NH_2$	$\rightarrow$	$H_2 + N_2H_2$	$6.60 \times 10^{-11}\exp(-6000/T_g)$	(120)
$NH_2 + NH_2$	$\rightarrow$	$NH + NH_3$	$8.30 \times 10^{-11}\exp(-5030/T_g)$	(120)
$NH_2 + NH_2$	$\rightarrow$	N_2H_4	8.00×10^{-11}	(120)
$NH_2 + N$	$\rightarrow$	$N_2 + H + H$	1.20×10^{-10}	(118)
$NH + NH_2$	$\rightarrow$	$H + N_2H_2$	$5.25 \times 10^{-11}\exp(-500/T_g)$	(120)

NH + NH	→	N_2H_2	3.50×10^{-12}	(118)
NH + NH + M	→	$H_2 + N_2 + M$	1.00×10^{-33}	(119)
NH + NH	→	$H + N_2H$	$2.29 \times 10^{-11}(T_g/300)^{0.50}\exp(-500/T_g)$	(120)
NH + NH	→	$NH_2 + N$	$5.72 \times 10^{-12}(T_g/300)^{0.50}\exp(-1000/T_g)$	(120)
NH + NH	→	$N_2 + H + H$	1.20×10^{-9}	(31)
NH + NH	→	$H_2 + N_2$	1.70×10^{-11}	(31)
NH + N	→	$H + N_2$	2.50×10^{-11}	(31)
$H_2(v) + N_2$	→	$H_2 + N_2$	1.00×10^{-13}	(31)
$N_2(v) + N_2$	→	$N_2 + N_2$	1.00×10^{-13}	(31)
$H_2(v) + N$	→	$H_2 + N$	1.00×10^{-13}	(31)
$N_2(v) + N$	→	$N_2 + N$	1.00×10^{-13}	(31)
$H_2(v) + H_2$	→	$H_2 + H_2$	1.00×10^{-13}	(31)
$N_2(v) + H_2$	→	$N_2 + H_2$	1.00×10^{-13}	(31)
$H_2(e) + N_2$	→	$H_2 + N_2$	1.00×10^{-13}	(31)
$H_2(e) + N$	→	$H_2 + N$	1.00×10^{-13}	(31)
$H(2P) + N_2$	→	$H + N_2$	1.00×10^{-13}	(31)
H(2P) + N	→	H + N	1.00×10^{-13}	(31)
$N_2(A^3\Sigma_u^+) + CH_4$	→	$N_2 + CH_3 + H$	1.50×10^{-12}	(119)
$N_2(a'\Sigma_u^-) + CH_4$	→	$N_2 + C + 2H_2$	3.00×10^{-10}	(119)
$N_2(a'\Sigma_u^-) + CH_4$	→	$N_2 + CH_3 + H$	3.00×10^{-10}	(119)
$N_2(a'\Sigma_u^-) + CH_4$	→	$N_2 + CH_2 + H_2$	3.00×10^{-10}	(121)
$N_2(A^3\Sigma_u^+) + CH_4$	→	$N_2 + CH_2 + H_2$	1.35×10^{-13}	(120)
$N_2(A^3\Sigma_u^+) + C_3H_8$	→	$N_2 + C_3H_6 + H_2$	1.30×10^{-12}	(119)
$N_2(a'\Sigma_u^-) + C_3H_8$	→	$N_2 + C_3H_6 + H_2$	3.00×10^{-10}	(120)
$N_2(A^3\Sigma_u^+) + C_3H_6$	→	$N_2 + C_3H_5 + H$	1.40×10^{-10}	(120)

$N_2(a'\Sigma_u^-)$ + C_3H_6	→	N_2 + C_3H_5 + H	1.40×10^{-10}	(120)
$N_2(A^3\Sigma_u^+)$ + C_3H_6	→	N_2 + C_2H_3 + CH_3	1.40×10^{-10}	(120)
$N_2(a'\Sigma_u^-)$ + C_3H_6	→	N_2 + C_2H_3 + CH_3	1.40×10^{-10}	(120)
$N_2(A^3\Sigma_u^+)$ + C_2H_6	→	N_2 + C_2H_4 + H_2	$1.80 \times 10^{-10}\exp(-1980/T_g)$	(120)
$N_2(a'\Sigma_u^-)$ + C_2H_6	→	N_2 + C_2H_4 + H_2	$5.00 \times 10^{-8}\exp(-1980/T_g)$	(120)
$N_2(A^3\Sigma_u^+)$ + C_2H_4	→	N_2 + C_2H_3 + H	5.50×10^{-11}	(120)
$N_2(a'\Sigma_u^-)$ + C_2H_4	→	N_2 + C_2H_3 + H	2.00×10^{-10}	(120)
$N_2(A^3\Sigma_u^+)$ + C_2H_4	→	N_2 + C_2H_2 + H_2	1.10×10^{-10}	(120)
$N_2(a'\Sigma_u^-)$ + C_2H_4	→	N_2 + C_2H_2 + H_2	2.00×10^{-10}	(120)
$N_2(A^3\Sigma_u^+)$ + C_2H_2	→	N_2 + C_2H + H_2	2.00×10^{-10}	(120)
$N_2(a'\Sigma_u^-)$ + C_2H_2	→	N_2 + C_2H + H_2	3.00×10^{-10}	(120)
$N_2(A^3\Sigma_u^+)$ + CH_3	→	N_2 + CH_2 + H	4.50×10^{-11}	(119)
$N_2(A^3\Sigma_u^+)$ + $N_2(A^3\Sigma_u^+)$	→	$N_2(A^3\Sigma_u^+)$ + N_2	2.00×10^{-12}	(31)
$N_2(A^3\Sigma_u^+)$ + $N_2(a'\Sigma_u^-)$	→	N_2^+ + N_2 + e^-	1.00×10^{-12}	(31)
$N_2(a'\Sigma_u^-)$ + $N_2(a'\Sigma_u^-)$	→	N_2^+ + N_2 + e^-	5.00×10^{-13}	(31)
$N_2(a'\Sigma_u^-)$ + $N_2(a'\Sigma_u^-)$	→	$N_2(a'\Sigma_u^-)$ + N_2	2.00×10^{-12}	(31)
$N_2(a'\Sigma_u^-)$ + N_2	→	N_2 + N_2	3.70×10^{-16}	(31)
$N_2(a'\Sigma_u^-)$ + N	→	N_2 + N	2.00×10^{-11}	(31)
$N_2(A^3\Sigma_u^+)$ + HCN	→	N_2 + CN + H	6.00×10^{-12}	(119)
N(2P) + H_2	→	NH + H	$4.60 \times 10^{-11}\exp(-880/T_g)$	(31)
N(2P) + NH_3	→	NH + NH_2	5.00×10^{-11}	(122)
N(2P) + M	→	N + M	2.40×10^{-14}	(31)
CH_2 + O_2	→	CO_2 + 2H	$1.08 \times 10^{-11}\exp(-758/T_g)$	(123)
CH_2 + O_2	→	CO + OH + H	$1.08 \times 10^{-11}\exp(-758/T_g)$	(123)
CH + O	→	OH + C	$2.52 \times 10^{-11}\exp(-2380/T_g)$	(124)

$C_2H_6 + O$	→	$C_2H_5 + OH$	$6.10 \times 10^{-11}(T_g/298)^{0.60}\exp(-3680/T_g)$	(60)
$H + OH$	→	$H_2 + O$	$6.86 \times 10^{-14}(T_g/298)^{2.80}\exp(-1950/T_g)$	(60)
$H + HO_2$	→	$H_2O + O(1D)$	$3.92 \times 10^{-12}(T_g/298)^{1.55}\exp(80.59/T_g)$	(125)
$OH + CH_3OH$	→	$H_2O + CH_2O + H$	$1.10 \times 10^{-12}(T_g/298)^{1.44}\exp(-56.53/T_g)$	(126)
$H_2O_2 + CH_2OH$	→	$CH_3OH + HO_2$	6.56×10^{-17}	(85)
$CH_3 + O_2$	→	$CH_2O + OH$	$5.65 \times 10^{-13}\exp(-4500/T_g)$	(127)
$CH_3 + O_2$	→	$CH_3O + O$	$2.19 \times 10^{-10}\exp(-15756/T_g)$	(61)
$CH_3 + O_2$	→	$CHO + H_2O$	1.66×10^{-12}	(128)
$CH_2 + CH_3O_2$	→	$CH_2O + CH_3O$	3.01×10^{-11}	(60)
$N_2(A^3\Sigma_u^+) + CH_4$	→	$N_2 + CH_4$	3.20×10^{-15}	(129)
$N_2(B^3\Pi_g) + CH_4$	→	$N_2(A^3\Sigma_u^+) + CH_4$	2.85×10^{-10}	(129)
$N_2(B^3\Pi_g) + CO_2$	→	$N_2(A^3\Sigma_u^+) + CO_2$	1.90×10^{-10}	(130-131)
$N_2(B^3\Pi_g) + CH_4$	→	$N_2 + CH_4$	0.15×10^{-10}	(129)
$N_2(B^3\Pi_g) + CO_2$	→	$N_2 + CO_2$	0.10×10^{-10}	(130-131)
$N_2(a'\Sigma_u^-) + CH_4$	→	$N_2 + CH_4$	3.00×10^{-10}	(129)
$N_2(a'\Sigma_u^-) + CO_2$	→	$N_2 + CO_2$	2.50×10^{-10}	(132)
$N_2(A^3\Sigma_u^+) + CO_2$	→	$N_2 + CO_2$	9.90×10^{-15}	(133)
$N_2(A^3\Sigma_u^+) + H_2$	→	$N_2 + 2H$	2.40×10^{-15}	(129)
$N_2(A^3\Sigma_u^+) + H_2$	→	$N_2 + H_2$	2.10×10^{-10}	(129)
$N_2(A^3\Sigma_u^+) + H$	→	$N_2 + H$	2.10×10^{-10}	(129)
$N_2(B^3\Pi_g) + H_2$	→	$N_2(A^3\Sigma_u^+) + H_2$	0.24×10^{-10}	(129)
$N_2(a'\Sigma_u^-) + H_2$	→	$N_2 + 2H$	2.60×10^{-11}	(129)
$N_2(a'\Sigma_u^-) + H$	→	$N_2 + H$	2.10×10^{-10}	(129)
$N_2(a'\Sigma_u^-) + H_2$	→	$N_2 + H_2$	2.60×10^{-10}	(129)

$N_2(B^3\Pi_g) + N_2O$	→	$N_2 + N_2 + O$	0.58×10^{-10}	(134)
$N_2(B^3\Pi_g) + N_2O$	→	$N_2 + N + NO$	0.58×10^{-10}	(134)
$N_2(A^3\Sigma_u^+) + CO_2$	→	$N_2 + CO + O$	1.54×10^{-12}	(135)
$N_2(B^3\Pi_g) + CO_2$	→	$N_2 + CO + O$	8.50×10^{-11}	(134)
O(1D) + CH_4	→	$CH_3 + OH$	3.11×10^{-10}	(136)
O(1D) + CH_4	→	CH_3OH	4.98×10^{-11}	(137)
O(1D) + CH_4	→	$CH_2O + H_2$	1.50×10^{-11}	(138)
O(1D) + CH_4	→	$CH_2OH + H$	6.90×10^{-12}	(138-139)
O(1D) + CO	→	CO_2	8.00×10^{-11}	(140)
O(1D) + CO	→	CO + O	5.00×10^{-11}	(141)
$CH_2O + O$	→	CO + OH + H	1.00×10^{-10}	(142)
$CH_2O + O$	→	CHO + OH	$1.78 \times 10^{-11}(T_g/298)^{0.57}\exp(-1390/T_g)$	(61)
$CH_2O + O_2$	→	$CHO + HO_2$	$3.40 \times 10^{-11}\exp(-19605/T_g)$	(60)
O_2(a1) + O	→	O_2 + O	7.00×10^{-16}	(53)
O_2(a1) + N	→	NO + O	$2.00 \times 10^{-14}\exp(-600/T_g)$	(53)
O_2(a1) + O_2	→	$O_2 + O_2$	$3.80 \times 10^{-18}\exp(-205/T_g)$	(53)
O_2(a1) + N_2	→	$O_2 + N_2$	3.00×10^{-21}	(53)
O_2(a1) + NO	→	O_2 + NO	2.50×10^{-21}	(53)
O_2(a1) + O_2(a1)	→	O_2 + O_2(b1)	$7.00 \times 10^{-28}(T_g)^{3.8}\exp(700/T_g)$	(53)
O + O_3	→	O_2 + O_2(a1)	$1.00 \times 10^{-11}\exp(-2300/T_g)$	(53)
O_2(b1) + O	→	O + O_2(a1)	8.10×10^{-14}	(53)
O_2(b1) + O	→	O(1D) + O_2	$3.40 \times 10^{-11}(T_g/300)^{-0.10}\exp(-4200/T_g)$	(53)
O_2(b1) + O_2	→	O_2 + O_2(a1)	$4.30 \times 10^{-22}(T_g)^{2.4}\exp(-281/T_g)$	(53)
O_2(b1) + N_2	→	N_2 + O_2(a1)	$1.70 \times 10^{-15}(T_g/300)^{1.0}$	(53)

O_2(b1) + NO	→	NO + O_2(a1)	6.00×10^{-14}	(53)
O_2(b1) + O_3	→	$2O_2$ + O	2.20×10^{-11}	(53)
O(1D) + O_2	→	O + O_2(a1)	1.00×10^{-12}	(53)
O(1D) + O_2	→	O + O_2(b1)	$2.60 \times 10^{-11}\exp(67/T_g)$	(53)
O(1S) + O_2(a1)	→	O(1D) + + O_2(b1)	2.90×10^{-11}	(53)
O(1S) + O_2(a1)	→	3O	3.20×10^{-11}	(53)
$N_2(A^3\Sigma_u^+) + N_2(a'\Sigma_u^-)$	→	N_4^+	4.00×10^{-12}	(53)
$N_2(a'\Sigma_u^-) + N_2(a'\Sigma_u^-)$	→	$N_3^+ + N_2$	1.00×10^{-11}	(53)
N + N	→	$N_2^+ + e^-$	$2.70 \times 10^{-11}\exp(-67400/T_g)$	(53)
O_2(a1) + H	→	OH + O	$1.83 \times 10^{-10}\exp(-3188/T_g)$	(143)
O_2(b1) + H	→	OH + O	$1.83 \times 10^{-10}\exp(-1620/T_g)$	(143)
O_2(a1) + H_2	→	HO_2 + H	$3.49 \times 10^{-11}\exp(-18216/T_g)$	(143)
O_2(b1) + H_2	→	HO_2 + H	$3.49 \times 10^{-11}\exp(-11508/T_g)$	(143)
O_2(a1) + OH	→	HO_2 + O	$2.16 \times 10^{-11}\exp(-17132/T_g)$	(143)
O_2(b1) + OH	→	HO_2 + O	$2.16 \times 10^{-11}\exp(-10111/T_g)$	(143)
$C_2H_6 + CH_2$	→	C_3H_8	4.80×10^{-12}	(144)
$CH_3O_2 + CH_3$	→	$CH_3O + CH_3O$	4.00×10^{-11}	(60)
CH_3O_2 + NO	→	$CH_3O + NO_2$	$4.20 \times 10^{-11}\exp(180/T_g)$	(145)
O(1D) + H_2O	→	OH + OH	2.20×10^{-10}	(138)
O(1D) + CH_3OH	→	CH_2OH + OH	2.99×10^{-10}	(146)
O(1D) + CH_2O	→	CO + H_2O	1.66×10^{-10}	(146)
CO_2(e1) + M	→	CO_2 + M	1.00×10^{-11}	(147)
CO_2(e2) + M	→	CO_2 + M	1.00×10^{-11}	(147)

Table S4. Ion-neutral reactions included in the model, as well as the corresponding rate coefficients and the references where these data were adopted from. The rate constants are in $cm^3\ s^{-1}$ or $cm^6\ s^{-1}$ for binary or ternary reactions, respectively.

CH_5^+	+	CH_2	→	CH_3^+	+	CH_4			9.60×10^{-10}	(59)
CH_5^+	+	CH	→	CH_2^+	+	CH_4			6.90×10^{-10}	(59)
CH_5^+	+	C	→	CH^+	+	CH_4			1.20×10^{-09}	(59)
CH_5^+	+	C_2H_6	→	$C_2H_5^+$	+	H_2	+	CH_4	2.25×10^{-10}	(148)
CH_5^+	+	C_2H_4	→	$C_2H_5^+$	+	CH_4			1.50×10^{-09}	(59)
CH_5^+	+	C_2H_2	→	$C_2H_3^+$	+	CH_4			1.60×10^{-09}	(59)
CH_5^+	+	C_2H	→	$C_2H_2^+$	+	CH_4			9.00×10^{-10}	(59)
CH_5^+	+	C_2	→	C_2H^+	+	CH_4			9.50×10^{-10}	(59)
CH_5^+	+	H	→	CH_4^+	+	H_2			1.50×10^{-10}	(59)
CH_5^+	+	O	→	H_3O^+	+	CH_2			2.20×10^{-10}	(59)
CH_5^+	+	H_2O	→	H_3O^+	+	CH_4			3.70×10^{-09}	(59)
CH_5^+	+	OH	→	H_2O^+	+	CH_4			7.00×10^{-10}	(59)
CH_4^+	+	CH_4	→	CH_5^+	+	CH_3			1.50×10^{-09}	(59)
CH_4^+	+	C_2H_6	→	$C_2H_4^+$	+	CH_4	+	H_2	1.91×10^{-09}	(148)
CH_4^+	+	C_2H_4	→	$C_2H_5^+$	+	CH_3			4.23×10^{-10}	(59)
CH_4^+	+	C_2H_4	→	$C_2H_4^+$	+	CH_4			1.38×10^{-09}	(59)
CH_4^+	+	C_2H_2	→	$C_2H_3^+$	+	CH_3			1.23×10^{-09}	(59)
CH_4^+	+	C_2H_2	→	$C_2H_2^+$	+	CH_4			1.13×10^{-09}	(59)
CH_4^+	+	H_2	→	CH_5^+	+	H			3.30×10^{-11}	(59)
CH_4^+	+	H	→	CH_3^+	+	H_2			1.00×10^{-11}	(59)
CH_4^+	+	O	→	CH_3^+	+	OH			1.00×10^{-09}	(59)
CH_4^+	+	O_2	→	O_2^+	+	CH_4			3.90×10^{-10}	(59)
CH_4^+	+	H_2O	→	H_3O^+	+	CH_3			2.60×10^{-09}	(59)

CH_3^+	+	CH_4	→	CH_4^+	+	CH_3		1.36×10^{-10}	(149)
CH_3^+	+	CH_4	→	$C_2H_5^+$	+	H_2		1.20×10^{-09}	(59)
CH_3^+	+	CH_2	→	$C_2H_3^+$	+	H_2		9.90×10^{-10}	(59)
CH_3^+	+	CH	→	$C_2H_2^+$	+	H_2		7.10×10^{-10}	(59)
CH_3^+	+	C	→	C_2H^+	+	H_2		1.20×10^{-09}	(59)
CH_3^+	+	C_2H_6	→	$C_2H_5^+$	+	CH_4		1.48×10^{-09}	(59)
CH_3^+	+	C_2H_4	→	$C_2H_3^+$	+	CH_4		3.50×10^{-10}	(59)
CH_3^+	+	C_2H_3	→	$C_2H_3^+$	+	CH_3		3.00×10^{-10}	(59)
CH_2^+	+	CH_4	→	CH_3^+	+	CH_3		1.38×10^{-10}	(150)
CH_2^+	+	CH_4	→	$C_2H_5^+$	+	H		3.60×10^{-10}	(59)
CH_2^+	+	CH_4	→	$C_2H_4^+$	+	H_2		8.40×10^{-10}	(59)
CH_2^+	+	CH_4	→	$C_2H_3^+$	+	H_2	+ H	2.31×10^{-10}	(150)
CH_2^+	+	CH_4	→	$C_2H_2^+$	+	$2H_2$		3.97×10^{-10}	(150)
CH_2^+	+	C	→	C_2H^+	+	H		1.20×10^{-09}	(59)
CH_2^+	+	H_2	→	CH_3^+	+	H		1.60×10^{-09}	(59)
CH^+	+	CH_4	→	$C_2H_4^+$	+	H		6.50×10^{-11}	(59)
CH^+	+	CH_4	→	$C_2H_3^+$	+	H_2		1.09×10^{-09}	(59)
CH^+	+	CH_4	→	$C_2H_2^+$	+	H_2	+ H	1.43×10^{-10}	(59)
CH^+	+	CH_2	→	C_2H^+	+	H_2		1.00×10^{-09}	(59)
CH^+	+	CH	→	C_2^+	+	H_2		7.40×10^{-10}	(59)
CH^+	+	C	→	C_2^+	+	H		1.20×10^{-09}	(59)
CH^+	+	H_2	→	CH_2^+	+	H		1.20×10^{-09}	(59)
CH^+	+	H	→	C^+	+	H_2		7.50×10^{-10}	(59)
CH^+	+	O	→	CO^+	+	H		3.50×10^{-10}	(59)
CH^+	+	O_2	→	CO^+	+	OH		1.00×10^{-11}	(59)

CH^+	+	O_2	→	O^+	+	CHO	1.00×10^{-11}	(59)
CH^+	+	H_2O	→	H_3O^+	+	C	5.80×10^{-10}	(59)
CH^+	+	OH	→	CO^+	+	H_2	7.50×10^{-10}	(59)
C^+	+	CH_4	→	$C_2H_3^+$	+	H	1.10×10^{-09}	(59)
C^+	+	CH_4	→	$C_2H_2^+$	+	H_2	4.00×10^{-10}	(59)
C^+	+	CH_3	→	$C_2H_2^+$	+	H	1.30×10^{-09}	(59)
C^+	+	CH_3	→	C_2H^+	+	H_2	1.00×10^{-09}	(59)
C^+	+	CH_2	→	CH_2^+	+	C	5.20×10^{-10}	(59)
C^+	+	CH_2	→	C_2H^+	+	H	5.20×10^{-10}	(59)
C^+	+	CH	→	CH^+	+	C	3.80×10^{-10}	(59)
C^+	+	CH	→	C_2^+	+	H	3.80×10^{-10}	(59)
C^+	+	C_2H_6	→	$C_2H_5^+$	+	CH	2.31×10^{-10}	(59)
C^+	+	C_2H_6	→	$C_2H_4^+$	+	CH_2	1.16×10^{-10}	(59)
C^+	+	C_2H_6	→	$C_2H_3^+$	+	CH_3	4.95×10^{-10}	(59)
C^+	+	C_2H_6	→	$C_2H_2^+$	+	CH_4	8.25×10^{-11}	(59)
C^+	+	C_2H_5	→	$C_2H_5^+$	+	C	5.00×10^{-10}	(59)
C^+	+	C_2H_4	→	$C_2H_4^+$	+	C	1.70×10^{-11}	(59)
C^+	+	C_2H_4	→	$C_2H_3^+$	+	CH	8.50×10^{-11}	(59)
C^+	+	O_2	→	O^+	+	CO	6.20×10^{-10}	(59)
C^+	+	O_2	→	CO^+	+	O	3.80×10^{-10}	(59)
C^+	+	OH	→	CO^+	+	H	7.70×10^{-10}	(59)
C^+	+	CO_2	→	CO^+	+	CO	1.10×10^{-09}	(59)
$C_2H_6^+$	+	C_2H_4	→	$C_2H_4^+$	+	C_2H_6	1.15×10^{-09}	(59)
$C_2H_6^+$	+	C_2H_2	→	$C_2H_5^+$	+	C_2H_3	2.47×10^{-10}	(59)
$C_2H_6^+$	+	H	→	$C_2H_5^+$	+	H_2	1.00×10^{-10}	(59)

$C_2H_6^+$	+	H_2O	→	H_3O^+	+	C_2H_5	2.95×10^{-09}	(59)
$C_2H_5^+$	+	H	→	$C_2H_4^+$	+	H_2	1.00×10^{-11}	(59)
$C_2H_5^+$	+	H_2O	→	H_3O^+	+	C_2H_4	1.40×10^{-09}	(59)
$C_2H_4^+$	+	C_2H_3	→	$C_2H_5^+$	+	C_2H_2	5.00×10^{-10}	(59)
$C_2H_4^+$	+	C_2H_3	→	$C_2H_3^+$	+	C_2H_4	5.00×10^{-10}	(59)
$C_2H_4^+$	+	H	→	$C_2H_3^+$	+	H_2	3.00×10^{-10}	(59)
$C_2H_4^+$	+	O	→	CH_3^+	+	CHO	1.08×10^{-10}	(59)
$C_2H_3^+$	+	C_2H_6	→	$C_2H_5^+$	+	C_2H_4	2.91×10^{-10}	(59)
$C_2H_3^+$	+	C_2H_4	→	$C_2H_5^+$	+	C_2H_2	8.90×10^{-10}	(59)
$C_2H_3^+$	+	C_2H_3	→	$C_2H_5^+$	+	C_2H	5.00×10^{-10}	(59)
$C_2H_3^+$	+	C_2H	→	$C_2H_2^+$	+	C_2H_2	3.30×10^{-10}	(59)
$C_2H_3^+$	+	H	→	$C_2H_2^+$	+	H_2	6.80×10^{-11}	(59)
$C_2H_3^+$	+	H_2O	→	H_3O^+	+	C_2H_2	1.11×10^{-09}	(59)
$C_2H_2^+$	+	CH_4	→	$C_2H_3^+$	+	CH_3	4.10×10^{-09}	(150)
$C_2H_2^+$	+	C_2H_6	→	$C_2H_5^+$	+	C_2H_3	1.31×10^{-10}	(148)
$C_2H_2^+$	+	C_2H_6	→	$C_2H_4^+$	+	C_2H_4	2.48×10^{-10}	(59)
$C_2H_2^+$	+	C_2H_4	→	$C_2H_4^+$	+	C_2H_2	4.14×10^{-10}	(59)
$C_2H_2^+$	+	C_2H_3	→	$C_2H_3^+$	+	C_2H_2	3.30×10^{-10}	(59)
$C_2H_2^+$	+	H_2	→	$C_2H_3^+$	+	H	1.00×10^{-11}	(59)
$C_2H_2^+$	+	H_2O	→	H_3O^+	+	C_2H	2.20×10^{-10}	(59)
C_2H^+	+	CH_4	→	$C_2H_2^+$	+	CH_3	3.74×10^{-10}	(59)
C_2H^+	+	CH_2	→	CH_3^+	+	C_2	4.40×10^{-10}	(59)
C_2H^+	+	CH	→	CH_2^+	+	C_2	3.20×10^{-10}	(59)
C_2H^+	+	H_2	→	$C_2H_2^+$	+	H	1.10×10^{-09}	(59)
C_2^+	+	CH_4	→	$C_2H_2^+$	+	CH_2	1.82×10^{-10}	(59)

C_2^+	+	CH_4	→	C_2H^+	+	CH_3	2.38×10^{-10}	(59)
C_2^+	+	CH_2	→	CH_2^+	+	C_2	4.50×10^{-10}	(59)
C_2^+	+	CH	→	CH^+	+	C_2	3.20×10^{-10}	(59)
C_2^+	+	C	→	C^+	+	C_2	1.10×10^{-10}	(59)
C_2^+	+	H_2	→	C_2H^+	+	H	1.10×10^{-09}	(59)
C_2^+	+	O	→	CO^+	+	C	3.10×10^{-10}	(59)
C_2^+	+	O_2	→	CO^+	+	CO	8.00×10^{-10}	(59)
C_2^+	+	H_2O	→	C_2H^+	+	OH	4.40×10^{-10}	(59)
C_2^+	+	OH	→	OH^+	+	C_2	6.50×10^{-10}	(59)
H_3^+	+	CH_4	→	CH_5^+	+	H_2	2.40×10^{-09}	(59)
H_3^+	+	CH_3	→	CH_4^+	+	H_2	2.10×10^{-09}	(59)
H_3^+	+	CH_2	→	CH_3^+	+	H_2	1.70×10^{-09}	(59)
H_3^+	+	CH	→	CH_2^+	+	H_2	1.20×10^{-09}	(59)
H_3^+	+	C	→	CH^+	+	H_2	2.00×10^{-09}	(59)
H_3^+	+	C_2H_6	→	$C_2H_5^+$	+	$2H_2$	2.40×10^{-09}	(59)
H_3^+	+	C_2H_5	→	$C_2H_6^+$	+	H_2	1.40×10^{-09}	(59)
H_3^+	+	C_2H_4	→	$C_2H_5^+$	+	H_2	1.15×10^{-09}	(59)
H_3^+	+	C_2H_4	→	$C_2H_3^+$	+	$2H_2$	1.15×10^{-09}	(59)
H_3^+	+	C_2H_3	→	$C_2H_4^+$	+	H_2	2.00×10^{-09}	(59)
H_3^+	+	C_2H_2	→	$C_2H_3^+$	+	H_2	3.50×10^{-09}	(59)
H_3^+	+	C_2H	→	$C_2H_2^+$	+	H_2	1.70×10^{-09}	(59)
H_3^+	+	C_2	→	C_2H^+	+	H_2	1.80×10^{-09}	(59)
H_3^+	+	O	→	OH^+	+	H_2	8.40×10^{-10}	(59)
H_3^+	+	O	→	H_2O^+	+	H	3.60×10^{-10}	(59)
H_3^+	+	OH	→	H_2O^+	+	H_2	1.30×10^{-09}	(59)

H_3^+	+	H_2O	→	H_3O^+	+	H_2			5.90×10^{-09}	(59)
H_3^+	+	H^-	→	H_2	+	H_2			2.30×10^{-07}	(59)
H_2^+	+	CH_4	→	CH_5^+	+	H			1.14×10^{-10}	(59)
H_2^+	+	CH_4	→	CH_4^+	+	H_2			1.40×10^{-09}	(59)
H_2^+	+	CH_4	→	CH_3^+	+	H_2	+	H	2.30×10^{-09}	(59)
H_2^+	+	CH_2	→	CH_3^+	+	H			1.00×10^{-09}	(59)
H_2^+	+	CH_2	→	CH_2^+	+	H_2			1.00×10^{-09}	(59)
H_2^+	+	CH	→	CH_2^+	+	H			7.10×10^{-10}	(59)
H_2^+	+	CH	→	CH^+	+	H_2			7.10×10^{-10}	(59)
H_2^+	+	C	→	CH^+	+	H			2.40×10^{-09}	(59)
H_2^+	+	C_2H_6	→	$C_2H_6^+$	+	H_2			2.94×10^{-10}	(59)
H_2^+	+	C_2H_6	→	$C_2H_5^+$	+	H_2	+	H	1.37×10^{-09}	(59)
H_2^+	+	C_2H_6	→	$C_2H_4^+$	+	$2H_2$			2.35×10^{-09}	(59)
H_2^+	+	C_2H_6	→	$C_2H_3^+$	+	$2H_2$	+	H	6.86×10^{-10}	(59)
H_2^+	+	C_2H_6	→	$C_2H_2^+$	+	$3H_2$			1.96×10^{-10}	(59)
H_2^+	+	C_2H_4	→	$C_2H_4^+$	+	H_2			2.21×10^{-09}	(59)
H_2^+	+	C_2H_4	→	$C_2H_3^+$	+	H_2	+	H	1.81×10^{-09}	(59)
H_2^+	+	C_2H_4	→	$C_2H_2^+$	+	$2H_2$			8.82×10^{-10}	(59)
H_2^+	+	C_2H_2	→	$C_2H_3^+$	+	H			4.80×10^{-10}	(59)
H_2^+	+	C_2H_2	→	$C_2H_2^+$	+	H_2			4.82×10^{-09}	(59)
H_2^+	+	C_2H	→	$C_2H_2^+$	+	H			1.00×10^{-09}	(59)
H_2^+	+	C_2H	→	C_2H^+	+	H_2			1.00×10^{-09}	(59)
H_2^+	+	C_2	→	C_2H^+	+	H			1.10×10^{-09}	(59)
H_2^+	+	C_2	→	C_2^+	+	H_2			1.10×10^{-09}	(59)
H_2^+	+	H_2	→	H_3^+	+	H			2.08×10^{-09}	(59)

H_2^+	+	H	→	H^+	+	H_2		6.40×10^{-10}	(59)
H_2^+	+	O	→	OH^+	+	H		1.50×10^{-09}	(59)
H_2^+	+	O_2	→	O_2^+	+	H_2		8.00×10^{-10}	(59)
H_2^+	+	OH	→	OH^+	+	H_2		7.60×10^{-10}	(59)
H_2^+	+	OH	→	H_2O^+	+	H		7.60×10^{-10}	(59)
H_2^+	+	H_2O	→	H_2O^+	+	H_2		3.90×10^{-09}	(59)
H_2^+	+	H_2O	→	H_3O^+	+	H		3.40×10^{-09}	(59)
H_2^+	+	CO	→	CO^+	+	H_2		6.44×10^{-10}	(59)
H^+	+	CH_4	→	CH_4^+	+	H		1.50×10^{-09}	(59)
H^+	+	CH_4	→	CH_3^+	+	H_2		2.30×10^{-09}	(59)
H^+	+	CH_3	→	CH_3^+	+	H		3.40×10^{-09}	(59)
H^+	+	CH_2	→	CH_2^+	+	H		1.40×10^{-09}	(59)
H^+	+	CH_2	→	CH^+	+	H_2		1.40×10^{-09}	(59)
H^+	+	CH	→	CH^+	+	H		1.90×10^{-09}	(59)
H^+	+	C_2H_6	→	$C_2H_5^+$	+	H_2		1.30×10^{-09}	(148)
H^+	+	C_2H_6	→	$C_2H_4^+$	+	H_2	+ H	1.40×10^{-09}	(59)
H^+	+	C_2H_6	→	$C_2H_3^+$	+	$2H_2$		2.80×10^{-09}	(59)
H^+	+	C_2H_5	→	$C_2H_4^+$	+	H_2		1.65×10^{-09}	(59)
H^+	+	C_2H_5	→	$C_2H_3^+$	+	H_2	+ H	3.06×10^{-09}	(59)
H^+	+	C_2H_4	→	$C_2H_4^+$	+	H		1.00×10^{-09}	(59)
H^+	+	C_2H_4	→	$C_2H_3^+$	+	H_2		3.00×10^{-09}	(59)
H^+	+	C_2H_4	→	$C_2H_2^+$	+	H_2	+ H	1.00×10^{-09}	(59)
H^+	+	C_2H_3	→	$C_2H_3^+$	+	H		2.00×10^{-09}	(59)
H^+	+	C_2H_3	→	$C_2H_2^+$	+	H_2		2.00×10^{-09}	(59)
H^+	+	C_2H_2	→	$C_2H_2^+$	+	H		5.40×10^{-10}	(59)

H^+	+	C_2H	→	C_2H^+	+	H	1.50×10^{-09}	(59)
H^+	+	C_2H	→	C_2^+	+	H_2	1.50×10^{-09}	(59)
H^+	+	C_2	→	C_2^+	+	H	3.10×10^{-09}	(59)
H^+	+	O	→	O^+	+	H	3.44×10^{-10}	(59)
H^+	+	O_2	→	O_2^+	+	H	2.00×10^{-09}	(59)
H^+	+	OH	→	OH^+	+	H	2.10×10^{-09}	(59)
H^+	+	H_2O	→	H_2O^+	+	H	6.90×10^{-09}	(59)
H^-	+	CH_3	→	CH_4	+	e^-	1.00×10^{-09}	(59)
H^-	+	CH_2	→	CH_3	+	e^-	1.00×10^{-09}	(59)
H^-	+	CH	→	CH_2	+	e^-	1.00×10^{-10}	(59)
H^-	+	C	→	CH	+	e^-	1.00×10^{-09}	(59)
H^-	+	C_2H	→	C_2H_2	+	e^-	1.00×10^{-09}	(59)
H^-	+	C_2	→	C_2H	+	e^-	1.00×10^{-09}	(59)
H^-	+	H	→	H_2	+	e^-	1.30×10^{-09}	(59)
H^-	+	O	→	OH	+	e^-	1.00×10^{-09}	(59)
H^-	+	OH	→	H_2O	+	e^-	1.00×10^{-10}	(59)
H^-	+	H_2O	→	OH^-	+	H_2	3.80×10^{-09}	(59)
O^+	+	CH_4	→	CH_4^+	+	O	8.90×10^{-10}	(59)
O^+	+	CH_4	→	CH_3^+	+	OH	1.10×10^{-10}	(59)
O^+	+	CH_2	→	CH_2^+	+	O	9.70×10^{-10}	(59)
O^+	+	CH	→	CH^+	+	O	3.50×10^{-10}	(59)
O^+	+	CH	→	CO^+	+	H	3.50×10^{-10}	(59)
O^+	+	C_2H_4	→	$C_2H_4^+$	+	O	7.00×10^{-11}	(59)
O^+	+	C_2H_4	→	$C_2H_3^+$	+	OH	2.10×10^{-10}	(59)
O^+	+	C_2H_4	→	$C_2H_2^+$	+	H_2O	1.12×10^{-09}	(59)

O^+	+	C_2H_2			→	$C_2H_2^+$	+	O	3.90×10^{-11}	(59)
O^+	+	C_2H			→	C_2H^+	+	O	4.60×10^{-10}	(59)
O^+	+	C_2H			→	CO^+	+	CH	4.60×10^{-10}	(59)
O^+	+	C_2			→	C_2^+	+	O	4.80×10^{-10}	(59)
O^+	+	C_2			→	CO^+	+	C	4.80×10^{-10}	(59)
O^+	+	H_2			→	OH^+	+	H	1.70×10^{-09}	(59)
O^+	+	H			→	H^+	+	O	5.82×10^{-10}	(59)
O^+	+	O	+	O_2	→	O_2^+	+	O_2	1.00×10^{-29}	(19)
O^+	+	O_2			→	O_2^+	+	O	2.00×10^{-11}	(19)
O^+	+	O_3			→	O_2^+	+	O_2	1.00×10^{-10}	(22)
O^+	+	OH			→	OH^+	+	O	3.60×10^{-10}	(59)
O^+	+	OH			→	O_2^+	+	H	3.60×10^{-10}	(59)
O^+	+	H_2O			→	H_2O^+	+	O	3.20×10^{-09}	(59)
O^+	+	CO_2			→	O_2^+	+	CO	9.40×10^{-10}	(59)
O^+	+	CO			→	CO^+	+	O	1.15×10^{-18}	(59)
O_2^+	+	CH_2			→	CH_2^+	+	O_2	4.30×10^{-10}	(59)
O_2^+	+	CH			→	CH^+	+	O_2	3.10×10^{-10}	(59)
O_2^+	+	C			→	CO^+	+	O	5.20×10^{-11}	(59)
O_2^+	+	C			→	C^+	+	O_2	5.20×10^{-11}	(59)
O_2^+	+	C_2H_4			→	$C_2H_4^+$	+	O_2	6.80×10^{-10}	(59)
O_2^+	+	C_2H_2			→	$C_2H_2^+$	+	O_2	1.11×10^{-09}	(59)
O_2^+	+	C_2			→	C_2^+	+	O_2	4.10×10^{-10}	(59)
O_2^+	+	C_2			→	CO^+	+	CO	4.10×10^{-10}	(59)
O_2^+	+	O_2	+	O_2	→	O_4^+	+	O_2	2.40×10^{-30}	(22)
O_4^+	+	O			→	O_2^+	+	O_3	3.00×10^{-10}	(22)

O_4^+	+	O_2			→	O_2^+	+	O_2	+	O_2	1.73×10^{-13}	(22)
O^-	+	CH_4			→	OH^-	+	CH_3			1.00×10^{-10}	(59)
O^-	+	C			→	CO	+	e^-			5.00×10^{-10}	(59)
O^-	+	H_2			→	H_2O	+	e^-			7.00×10^{-10}	(59)
O^-	+	H_2			→	OH^-	+	H			3.00×10^{-11}	(59)
O^-	+	H			→	OH	+	e^-			5.00×10^{-10}	(59)
O^-	+	O			→	O_2	+	e^-			2.30×10^{-10}	(151)
O^-	+	O_2			→	O	+	O_2	+	e^-	k = f(E/N)	(19)
O^-	+	O_2			→	O_2^-	+	O			k = f(E/N)	(19)
O^-	+	O_2			→	O_3	+	e^-			5.00×10^{-15}	(19)
O^-	+	O_2	+	O_2	→	O_3^-	+	O_2			1.10×10^{-30}	(19)
O^-	+	O_3			→	O_3^-	+	O			5.30×10^{-10}	(19)
O^-	+	O_3			→	O_2	+	O_2	+	e^-	3.00×10^{-10}	(152)
O^-	+	CO			→	CO_2	+	e^-			6.50×10^{-10}	(59)
O_2^-	+	O			→	O^-	+	O_2			3.30×10^{-10}	(19)
O_2^-	+	O			→	O_3	+	e^-			3.30×10^{-10}	(151)
O_2^-	+	O_2			→	O_2	+	O_2	+	e^-	2.18×10^{-18}	(19)
O_2^-	+	O_2	+	O_2	→	O_4^-	+	O_2			3.50×10^{-31}	(22)
O_2^-	+	O_3			→	O_3^-	+	O_2			4.00×10^{-10}	(19)
O_3^-	+	O			→	O^-	+	O_3			1.00×10^{-13}	(152)
O_3^-	+	O			→	O_2	+	O_2	+	e^-	3.00×10^{-10}	(22)
O_3^-	+	O			→	O_2^-	+	O_2			3.20×10^{-10}	(22)
O_3^-	+	O_2			→	O_3	+	O_2	+	e^-	2.30×10^{-11}	(19)
O_3^-	+	O_3			→	O_2	+	O_2	+	O_2	1.00×10^{-12}	(152)
O_4^-	+	O			→	O_3^-	+	O_2			4.00×10^{-10}	(22)

O_4^-	+	O	→	O^-	+	O_2	+	O_2	3.00×10^{-10}	(22)
O_4^-	+	O_2	→	O_2^-	+	O_2	+	O_2	3.08×10^{-12}	(22)
CO_2^+	+	CH_4	→	CH_4^+	+	CO_2			5.50×10^{-10}	(59)
CO_2^+	+	C_2H_4	→	$C_2H_4^+$	+	CO_2			1.50×10^{-10}	(59)
CO_2^+	+	C_2H_2	→	$C_2H_2^+$	+	CO_2			7.30×10^{-10}	(59)
CO_2^+	+	O_2	→	O_2^+	+	CO_2			5.30×10^{-11}	(59)
CO_2^+	+	O	→	O_2^+	+	CO			1.64×10^{-10}	(59)
CO_2^+	+	O	→	O^+	+	CO_2			9.62×10^{-11}	(59)
CO_2^+	+	H_2O	→	H_2O^+	+	CO_2			2.04×10^{-09}	(59)
CO^+	+	CH_4	→	CH_4^+	+	CO			7.93×10^{-10}	(59)
CO^+	+	CH_2	→	CH_2^+	+	CO			4.30×10^{-10}	(59)
CO^+	+	CH	→	CH^+	+	CO			3.20×10^{-10}	(59)
CO^+	+	C	→	C^+	+	CO			1.10×10^{-10}	(59)
CO^+	+	C_2H	→	C_2H^+	+	CO			3.90×10^{-10}	(59)
CO^+	+	C_2	→	C_2^+	+	CO			8.40×10^{-10}	(59)
CO^+	+	H	→	H^+	+	CO			7.50×10^{-10}	(59)
CO^+	+	O_2	→	O_2^+	+	CO			1.20×10^{-10}	(59)
CO^+	+	O	→	O^+	+	CO			1.40×10^{-10}	(59)
CO^+	+	CO_2	→	CO_2^+	+	CO			1.00×10^{-09}	(59)
CO^+	+	H_2O	→	H_2O^+	+	CO			1.72×10^{-09}	(59)
CO^+	+	OH	→	OH^+	+	CO			3.10×10^{-10}	(59)
H_3O^+	+	CH_2	→	CH_3^+	+	H_2O			9.40×10^{-10}	(59)
H_3O^+	+	CH	→	CH_2^+	+	H_2O			6.80×10^{-10}	(59)
H_3O^+	+	C_2H_3	→	$C_2H_4^+$	+	H_2O			2.00×10^{-09}	(59)
H_3O^+	+	C_2	→	C_2H^+	+	H_2O			9.20×10^{-10}	(59)

H_2O^+	+	CH_4	→	H_3O^+	+	CH_3		1.40×10^{-09}	(59)
H_2O^+	+	CH_2	→	CH_3^+	+	OH		4.70×10^{-10}	(59)
H_2O^+	+	CH_2	→	CH_2^+	+	H_2O		4.70×10^{-10}	(59)
H_2O^+	+	CH	→	CH_2^+	+	OH		3.40×10^{-10}	(59)
H_2O^+	+	CH	→	CH^+	+	H_2O		3.40×10^{-10}	(59)
H_2O^+	+	C	→	CH^+	+	OH		1.10×10^{-09}	(59)
H_2O^+	+	C_2H_6	→	H_3O^+	+	C_2H_5		1.33×10^{-09}	(59)
H_2O^+	+	C_2H_6	→	$C_2H_6^+$	+	H_2O		6.40×10^{-11}	(59)
H_2O^+	+	C_2H_6	→	$C_2H_4^+$	+	H_2O	+ H_2	1.92×10^{-10}	(59)
H_2O^+	+	C_2H_4	→	$C_2H_4^+$	+	H_2O		1.50×10^{-09}	(59)
H_2O^+	+	C_2H_2	→	$C_2H_2^+$	+	H_2O		1.90×10^{-09}	(59)
H_2O^+	+	C_2H	→	$C_2H_2^+$	+	OH		4.40×10^{-10}	(59)
H_2O^+	+	C_2H	→	C_2H^+	+	H_2O		4.40×10^{-10}	(59)
H_2O^+	+	C_2	→	C_2H^+	+	OH		4.70×10^{-10}	(59)
H_2O^+	+	C_2	→	C_2^+	+	H_2O		4.70×10^{-10}	(59)
H_2O^+	+	H_2	→	H_3O^+	+	H		6.40×10^{-10}	(59)
H_2O^+	+	O_2	→	O_2^+	+	H_2O		4.60×10^{-10}	(59)
H_2O^+	+	O	→	O_2^+	+	H_2		4.00×10^{-11}	(59)
H_2O^+	+	H_2O	→	H_3O^+	+	OH		2.10×10^{-09}	(59)
H_2O^+	+	OH	→	H_3O^+	+	O		6.90×10^{-10}	(59)
OH^+	+	CH_4	→	CH_5^+	+	O		1.95×10^{-10}	(59)
OH^+	+	CH_4	→	H_3O^+	+	CH_2		1.31×10^{-09}	(59)
OH^+	+	CH_2	→	CH_3^+	+	O		4.80×10^{-10}	(59)
OH^+	+	CH_2	→	CH_2^+	+	OH		4.80×10^{-10}	(59)
OH^+	+	CH	→	CH_2^+	+	O		3.50×10^{-10}	(59)

OH^+	+	CH			→	CH^+	+	OH			3.50×10^{-10}	(59)
OH^+	+	C			→	CH^+	+	O			1.20×10^{-09}	(59)
OH^+	+	C_2H_6			→	H_3O^+	+	C_2H_4			1.60×10^{-10}	(59)
OH^+	+	C_2H_6			→	$C_2H_6{}^+$	+	OH			4.80×10^{-11}	(59)
OH^+	+	C_2H_6			→	$C_2H_5{}^+$	+	H_2	+	O	3.20×10^{-10}	(59)
OH^+	+	C_2H_6			→	$C_2H_4{}^+$	+	H_2	+	OH	1.04×10^{-09}	(59)
OH^+	+	C_2H			→	$C_2H_2{}^+$	+	O			4.50×10^{-10}	(59)
OH^+	+	C_2H			→	C_2H^+	+	OH			4.50×10^{-10}	(59)
OH^+	+	C_2			→	C_2H^+	+	O			4.80×10^{-10}	(59)
OH^+	+	C_2			→	$C_2{}^+$	+	OH			4.80×10^{-10}	(59)
OH^+	+	H_2			→	H_2O^+	+	H			1.01×10^{-09}	(59)
OH^+	+	O_2			→	$O_2{}^+$	+	OH			5.90×10^{-10}	(59)
OH^+	+	O			→	$O_2{}^+$	+	H			7.10×10^{-10}	(59)
OH^+	+	H_2O			→	H_2O^+	+	OH			1.59×10^{-09}	(59)
OH^+	+	H_2O			→	H_3O^+	+	O			1.30×10^{-09}	(59)
OH^+	+	OH			→	H_2O^+	+	O			7.00×10^{-10}	(59)
OH^-	+	CH_3			→	CH_3OH	+	e^-			1.00×10^{-09}	(59)
OH^-	+	CH			→	CH_2O	+	e^-			5.00×10^{-10}	(59)
OH^-	+	C			→	CHO	+	e^-			5.00×10^{-10}	(59)
OH^-	+	H			→	H_2O	+	e^-			1.40×10^{-09}	(59)
CO_2	+	O^-	+	M	→	CO_3-	+	M			9.00×10^{-29}	(113)
CO_2	+	$O_2{}^-$			→	CO_4-	+				1.00×10^{-29}	(113)
CO_2	+	$O_3{}^-$			→	O_2	+	CO_3-			5.50×10^{-10}	(113)
CO_2	+	$O_4{}^-$			→	O_2	+	CO_4-			4.80×10^{-10}	(113)
CO_2	+	$CO_2{}^+$	+	M	→	$C_2O_4{}^+$	+	M			3.00×10^{-28}	(113)

CO_2	+	O_2^+	+	M	→	CO_4^+	+	M				2.30×10^{-29}	(113)
CO	+	CO_3^-			→	$2CO_2$	+	e^-				5.50×10^{-17}	(113)
CO	+	$C_2O_3^+$			→	$C_2O_2^+$	+	CO_2				1.10×10^{-09}	(113)
CO	+	$C_2O_4^+$			→	$C_2O_3^+$	+	CO_2				9.00×10^{-10}	(113)
CO	+	$C_2O_3^+$	+	M	→	$C_2O_2^+$	+	CO_2	+	M		2.60×10^{-26}	(113)
CO	+	$C_2O_4^+$	+	M	→	$C_2O_3^+$	+	CO_2	+	M		4.20×10^{-26}	(113)
O_2	+	$C_2O_2^+$			→	O_2^+	+	2CO				5.00×10^{-12}	(113)
O	+	CO_3^-			→	CO_2	+	O_2^-				8.00×10^{-11}	(113)
O	+	CO_4^-			→	O_2	+	CO_3^-				1.40×10^{-11}	(113)
O	+	CO_4^-			→	CO_2	+	O_3^-				1.40×10^{-11}	(113)
O_3	+	CO_4^-			→	CO_2	+	O_3^-	+	O_2		4.00×10^{-13}	(113)
$C_2O_2^+$	+	M	+	M	→	CO^+	+	CO	+	M		1.00×10^{-12}	(113)
$C_2O_4^+$	+	M	+	M	→	CO_2^+	+	CO_2	+	M		1.00×10^{-14}	(113)
O^-	+	N			→	NO	+	e^-				2.60×10^{-10}	(53)
O^-	+	NO			→	NO_2	+	e^-				2.60×10^{-10}	(53)
O^-	+	N_2(g, v)			→	N_2O	+	e^-				5.00×10^{-13}	(53)
O^-	+	$N_2(A^3\Sigma_u^+)$			→	O	+	N_2	+	e^-		2.20×10^{-09}	(53)
O^-	+	$N_2\left(B^3\Pi_g\right)$			→	O	+	N_2	+	e^-		1.90×10^{-09}	(53)
O_2^-	+	N			→	NO_2	+	+	e^-			5.00×10^{-10}	(53)
O_2^-	+	$N_2(A^3\Sigma_u^+)$			→	O_2	+	N_2	+	e^-		2.10×10^{-09}	(53)
O_2^-	+	$N_2\left(B^3\Pi_g\right)$			→	O_2	+	N_2	+	e^-		2.50×10^{-09}	(53)
O^-	+	NO_2			→	NO_2^-	+	O				1.20×10^{-09}	(53)
O^-	+	N_2O			→	NO^-	+	NO				2.00×10^{-10}	(53)
O^-	+	N_2O			→	N_2O^-	+	O				2.00×10^{-12}	(53)
O_2^-	+	NO_2			→	NO_2^-	+	O_2				7.00×10^{-10}	(53)

O_2^-	+	NO_3		→	NO_3^-	+	O_2		5.00×10^{-12}	(53)
O_3^-	+	NO		→	NO_3^-	+	O		1.00×10^{-11}	(53)
O_3^-	+	NO		→	NO_2^-	+	O_2		2.60×10^{-12}	(53)
O_3^-	+	NO_2		→	NO_2^-	+	O_3		7.00×10^{-11}	(53)
O_3^-	+	NO_2		→	NO_3^-	+	O_2		2.00×10^{-11}	(53)
O_3^-	+	NO_3		→	NO_3^-	+	O_3		5.00×10^{-10}	(53)
NO^-	+	O_2		→	O_2^-	+	NO		5.00×10^{-10}	(53)
NO^-	+	NO_2		→	NO_2^-	+	NO		7.40×10^{-10}	(53)
NO^-	+	N_2O		→	NO_2^-	+	N_2		2.80×10^{-14}	(53)
NO_2^-	+	O_3		→	NO_3^-	+	O_2		1.80×10^{-11}	(53)
NO_2^-	+	NO_2		→	NO_3^-	+	NO		4.00×10^{-12}	(53)
NO_2^-	+	NO_3		→	NO_3^-	+	NO_2		5.00×10^{-10}	(53)
NO_2^-	+	N_2O_5		→	NO_3^-	+	$2NO_2$		7.00×10^{-10}	(53)
NO_3^-	+	NO		→	NO_2^-	+	NO_2		3.00×10^{-15}	(53)
O_4^-	+	NO		→	NO_3^-	+	O_2		2.50×10^{-10}	(53)
O^-	+	NO	+ M	→	NO_2^-	+	M		1.00×10^{-29}	(53)
NO^-	+	N		→	N_2O	+	e^-		5.00×10^{-10}	(53)
O_3^-	+	N		→	NO	+	O_2	+ e^-	5.00×10^{-10}	(53)
N_2O^-	+	N		→	NO	+	N_2	+ e^-	5.00×10^{-10}	(53)
NO_2^-	+	N		→	NO	+	NO	+ e^-	5.00×10^{-10}	(53)
NO_3^-	+	N		→	NO	+	NO_2	+ e^-	5.00×10^{-10}	(53)
NO^-	+	O		→	NO_2	+	e^-		1.50×10^{-10}	(53)
N_2O^-	+	O		→	NO	+	NO	+ e^-	1.50×10^{-10}	(53)
NO_2^-	+	O		→	NO	+	O_2	+ e^-	1.50×10^{-10}	(53)
NO_3^-	+	O		→	NO	+	O_3	+ e^-	1.50×10^{-10}	(53)

O_3^-	+	$N_2(A^3\Sigma_u^+)$	→	N_2	+	O_3	+	e^-	2.10×10^{-09}	(53)
NO^-	+	$N_2(A^3\Sigma_u^+)$	→	N_2	+	NO	+	e^-	2.10×10^{-09}	(53)
N_2O^-	+	$N_2(A^3\Sigma_u^+)$	→	N_2	+	N_2O	+	e^-	2.10×10^{-09}	(53)
NO_2^-	+	$N_2(A^3\Sigma_u^+)$	→	N_2	+	NO_2	+	e^-	2.10×10^{-09}	(53)
NO_3^-	+	$N_2(A^3\Sigma_u^+)$	→	N_2	+	NO_3	+	e^-	2.10×10^{-09}	(53)
O_3^-	+	$N_2(B^3\Pi_g)$	→	N_2	+	O_3	+	e^-	2.50×10^{-09}	(53)
NO^-	+	$N_2(B^3\Pi_g)$	→	N_2	+	NO	+	e^-	2.50×10^{-09}	(53)
N_2O^-	+	$N_2(B^3\Pi_g)$	→	N_2	+	N_2O	+	e^-	2.50×10^{-09}	(53)
NO_2^-	+	$N_2(B^3\Pi_g)$	→	N_2	+	NO_2	+	e^-	2.50×10^{-09}	(53)
NO_3^-	+	$N_2(B^3\Pi_g)$	→	N_2	+	NO_3	+	e^-	2.50×10^{-09}	(53)
N^+	+	O	→	N	+	O^+			1.00×10^{-12}	(53)
N^+	+	O_2	→	N	+	O_2^+			2.80×10^{-10}	(53)
N^+	+	O_2	→	O	+	NO^+			2.50×10^{-10}	(53)
N^+	+	O_2	→	NO	+	O^+			2.80×10^{-10}	(53)
N^+	+	O_3	→	O_2	+	NO^+			5.00×10^{-10}	(53)
N^+	+	NO	→	N	+	NO^+			8.00×10^{-10}	(53)
N^+	+	NO	→	O	+	N_2^+			3.00×10^{-12}	(53)
N^+	+	NO	→	N_2	+	O^+			1.00×10^{-12}	(53)
O^+	+	N_2(g, v)	→	N	+	NO^+			$1.00 \times 10^{-12}\exp(-0.31/ T_g)$	(31)
O^+	+	NO	→	NO^+	+	O			2.40×10^{-11}	(53)
O^+	+	NO	→	O_2^+	+	N			3.00×10^{-12}	(53)
O^+	+	N(2D)	→	N^+	+	O			1.30×10^{-10}	(53)
O^+	+	N_2O	→	NO^+	+	NO			2.30×10^{-10}	(53)
O^+	+	N_2O	→	N_2O^+	+	O			2.20×10^{-10}	(53)
O^+	+	N_2O	→	O_2^+	+	N_2			2.00×10^{-11}	(53)

O^+	+	NO_2	→	NO_2^+	+	O		1.60×10^{-09}	(53)
N_2^+	+	O	→	O_2^+	+	N_2		$1.30 \times 10^{-10}\ (T_g/300)^{-0.5}$	(31)
N_2^+	+	O_2	→	NO^+	+	O		$1.00 \times 10^{-12}\exp(-0.31/\ T_g)$	(31)
N_2^+	+	O_3	→	O_2^+	+	O	+ N_2	1.00×10^{-10}	(53)
N_2^+	+	NO	→	NO^+	+	N_2		3.30×10^{-10}	(53)
N_2^+	+	N_2O	→	N_2O^+	+	N_2		5.00×10^{-10}	(53)
N_2^+	+	N_2O	→	NO^+	+	N_2	+ N	4.00×10^{-10}	(53)
O_2^+	+	N_2(g, v)	→	NO^+	+	NO		1.10×10^{-17}	(31)
O_2^+	+	N	→	NO^+	+	O		1.20×10^{-10}	(53)
O_2^+	+	NO	→	NO^+	+	O_2		6.30×10^{-10}	(53)
O_2^+	+	NO_2	→	NO^+	+	O_3		1.00×10^{-11}	(53)
O_2^+	+	NO_2	→	NO_2^+	+	O_2		6.60×10^{-10}	(53)
N_3^+	+	O_2	→	O_2^+	+	N	+ N_2	2.30×10^{-11}	(53)
N_3^+	+	O_2	→	NO_2^+	+	N_2		4.40×10^{-11}	(53)
N_3^+	+	NO	→	NO^+	+	N	+ N_2	7.00×10^{-11}	(53)
N_3^+	+	NO	→	N_2O^+	+	N_2		7.00×10^{-11}	(53)
NO_2^+	+	NO	→	NO^+	+	NO_2		2.90×10^{-10}	(53)
N_2O^+	+	NO	→	NO^+	+	N_2O		2.90×10^{-10}	(53)
N_4^+	+	O_2	→	O_2^+	+	N_2	+ N_2	2.50×10^{-10}	(53)
N_4^+	+	O	→	O^+	+	N_2	+ N_2	2.50×10^{-10}	(53)
N_4^+	+	NO	→	NO^+	+	N_2	+ N_2	4.00×10^{-10}	(53)
O_4^+	+	N_2(g, v)	→	$O_2^+ N_2$	+	O_2		$4.60 \times 10^{-12} \left(T_{effN4} /300\right)^{2.50}\ exp(-2650 /T_{eff4})$	(53)

$O_2^+ N_2$	+	O_2			→	NO^+	+	$2O_2$				1.00×10^{-09}	(53)
$O_2^+ N_2$	+	$N_2(g, v)$			→	O_2^+	+	N_2	+	$N_2(g, v)$		$1.10 \times 10^{-6}(T_{effN4}/300)^{-5.30}\exp(-2360/T_{effN4})$	(53)
O_4^+	+	NO			→	O_4^+	+	N_2				1.00×10^{-10}	(53)
N^+	+	O	+	M	→	NO^+	+	M				1.00×10^{-29}	(53)
O^+	+	$N_2(g, v)$	+	M	→	NO^+	+	N	+	M		$6.00 \times 10^{-29}(T_{effN}/300)^{-2.00}$	(53)
O^+	+	N	+	M	→	NO^+	+	M				1.00×10^{-29}	(53)
O_2^+	+	$N_2(g, v)$	+	N_2	→	$O_2^+ N_2$	+	N_2				$9.00 \times 10^{-31}(T_{effN2}/300)^{-2.00}$	(53)
CO_3^-	+	NO			→	NO_2^-	+	CO_2				$1.10 \times 10^{-11}(T_g/300)^{0.50}$	(53)
CO_3^-	+	NO_2			→	NO_3^-	+	CO_2				$2.00 \times 10^{-10}(T_g/300)^{0.50}$	(53)
CO_4^-	+	NO			→	NO_3^-	+	CO_2				$1.10 \times 10^{-11}(T_g/300)^{0.50}$	(53)
NO^-	+	CO			→	NO	+	CO	+	e^-		5.00×10^{-13}	(53)
NO^-	+	CO_2			→	NO	+	CO_2	+	e^-		8.30×10^{-12}	(53)
N^+	+	N	+	M	→	N_2^+	+	M				1.70×10^{-29}	(53)
N^+	+	$N_2(g, v)$	+	N_2	→	N_3^+	+	N_2				$1.70 \times 10^{-11}(T_{effN}/300)^{2.10}$	(53)
N_2	+	$N_2(A^3\Sigma_u^+)$			→	N_3^+	+	N				3.00×10^{-10}	(53)

N_2^+	+	N			→	N^+	+	N_2			$7.20 \times 10^{-13}(T_{effN2}/300)^{1.00}$	(53)
N_2^+	+	N_2(g, v)	+	N_2	→	N_4^+	+	N_2			$5.20 \times 10^{-29}(T_{effN2}/300)^{-2.20}$	(53)
N_2^+	+	N_2(g, v)	+	N	→	N_3^+	+	N_2(g, v)			$9.00 \times 10^{-30}\exp(400.0/T_{effN4})$	(53)
N_3^+	+	N			→	N_2^+	+	N_2			6.60×10^{-11}	(53)
N_4^+	+	N_2(g, v)			→	N_2^+	+	N_2(g, v)			$\min(2.10 \times 10^{-16}\exp(\frac{T_{effN4}}{121}), 1.00 \times 10^{-10})$	(53)
N_4^+	+	N			→	N^+	+	$2N_2$			1.00×10^{-11}	(53)
H^+	+	H_2	+	M	→	H_3^+	+	M			1.00×10^{-29}	(31)
H^+	+	H	+	M	→	H_2^+	+	M			1.00×10^{-34}	(31)
H^+	+	N	+	M	→	N^+	+	H			5.00×10^{-11}	(31)
H^-	+	M			→	H	+	e^-			$2.70 \times 10^{-6}(T_g/300)^{0.50}\exp(-5590/T_g)$	(31)
H^-	+	H			→	H_2	+	e^-			1.30×10^{-09}	(31)
H^-	+	N			→	NH	+	e^-			1.00×10^{-09}	(31)
N_4^+	+	C_3H_8			→	$C_2H_5^+$	+	$2N_2$	+	CH_3	6.70×10^{-10}	(31)
N_4^+	+	C_3H_8			→	$C_2H_4^+$	+	$2N_2$	+	CH_4	4.30×10^{-10}	(31)
N_4^+	+	M			→	N_2^+	+	N_2	+	M	2.50×10^{-15}	(31)
N_3^+	+	NH_3			→	NH_3^+	+	N_2	+	N	2.10×10^{-09}	(122)
N_3^+	+	M			→	N_2^+	+	N	+	M	6.60×10^{-11}	(135)
N_2^+	+	C_3H_8			→	$C_2H_5^+$	+	N_2	+	CH_3	3.90×10^{-10}	(135)
N_2^+	+	C_3H_8			→	$C_2H_4^+$	+	N_2	+	CH_4	2.20×10^{-10}	(135)

N_2^+	+	C_3H_8			→	$C_2H_3^+$	+	N_2 + H_2	+	CH_3	5.20×10^{-10}	(135)
N_2^+	+	NH_3			→	NH_3^+	+	N_2			1.90×10^{-09}	(122)
N_2^+	+	N_2	+	M	→	N_4^+	+	M			$6.80 \times 10^{-29}(T_g/300)^{1.64}$	(31)
N_2^+	+	N	+	M	→	N_3^+	+	M			$9.30 \times 10^{-30}(T_g/300)^{1.00}\exp(-400/T_g)$	(31)
N^+	+	NH_3			→	NH_3^+	+	N			2.40×10^{-09}	(122)
N^+	+	N_2			→	N_2^+	+	N			1.00×10^{-09}	(31)
N^+	+	N_2	+	M	→	N_3^+	+	M			$9.30 \times 10^{-30}\exp(-400/T_g)$	(31)
N^+	+	H			→	H^+	+	N			2.00×10^{-09}	(31)
N^+	+	NH			→	N_2^+	+	H			3.70×10^{-10}	(31)
NH_3^+	+	H_2			→	NH_4^+	+	H			4.00×10^{-13}	(135)
NH_2^+	+	NH_3			→	NH_3^+	+	NH_2			1.10×10^{-09}	(135)
NH_2^+	+	NH_3			→	NH_4^+	+	NH			1.10×10^{-09}	(135)
NH_2^+	+	H_2			→	NH_3^+	+	NH			1.00×10^{-09}	(135)
NH^+	+	NH_3			→	NH_3^+	+	NH			1.80×10^{-09}	(135)
NH^+	+	NH_3			→	NH_4^+	+	N			6.00×10^{-10}	(135)
NH^+	+	NH_2			→	NH_2^+	+	NH			1.80×10^{-09}	(135)
O^-	+	O_2(a1)			→	O_3	+	e^-			3.00×10^{-10}	(53)
O^-	+	O_2(b1)			→	O	+	O_2	+	e^-	6.90×10^{-10}	(53)
O_2^-	+	O_2(a1)			→	$2O_2$	+	e^-			2.00×10^{-10}	(53)
O_2^-	+	O_2(b1)			→	$2O_2$	+	e^-			3.60×10^{-10}	(53)
O_4^+	+	O_2(a1)			→	$2O_2$	+	O_2^+			1.00×10^{-10}	(53)
O_4^+	+	O_2(b1)			→	$2O_2$	+	O_2^+			1.00×10^{-10}	(53)

O_4^-	+	O_2(a1)	$\rightarrow$	$2O_2$	+	O_2^-	1.00×10^{-10}	(53)
O_4^-	+	O_2(b1)	$\rightarrow$	$2O_2$	+	O_2^-	1.00×10^{-10}	(53)
O^-	+	O_2(a1)	$\rightarrow$	O	+	O_2^-	1.00×10^{-10}	(53)

Table S5. Ion-ion reactions included in the model, as well as the corresponding rate coefficients and the references where these data were adopted from. The rate constants are in $cm^3\ s^{-1}$ or $cm^6\ s^{-1}$ for binary or ternary reactions, respectively.

C^+	+	H^-			→	C	+	H			2.30×10^{-07}	(59)
H_2^+	+	H^-			→	H_2	+	H			2.30×10^{-07}	(59)
H^+	+	H^-			→	H	+	H			2.30×10^{-07}	(59)
H^-	+	O^+			→	H	+	O			2.30×10^{-07}	(59)
H^-	+	H_3O^+			→	H_2	+	OH	+	H	2.30×10^{-07}	(59)
H^-	+	H_3O^+			→	H_2O	+	H_2			2.30×10^{-07}	(59)
O^+	+	O^-			→	O	+	O			4.00×10^{-08}	(151)
O^+	+	O^-	+	O	→	O_2	+	O			2.00×10^{-25}	(19)
O^+	+	O^-	+	O_2	→	O_2	+	O_2			2.00×10^{-25}	(19)
O^+	+	O_2^-			→	O	+	O_2			2.70×10^{-07}	(151)
O^+	+	O_2^-	+	O_2	→	O_3	+	O_2			2.00×10^{-25}	(19)
O^+	+	O_3^-			→	O_3	+	O			1.00×10^{-07}	(19)
O_2^+	+	O^-			→	O	+	O_2			2.60×10^{-08}	(151)
O_2^+	+	O^-			→	O	+	O	+	O	2.60×10^{-08}	(151)
O_2^+	+	O^-	+	O_2	→	O_3	+	O_2			2.00×10^{-25}	(19)
O_2^+	+	O_2-			→	O_2	+	O_2			2.00×10^{-07}	(151)
O_2^+	+	O_2-			→	O_2	+	O	+	O	1.00×10^{-07}	(19)
O_2^+	+	O_2-	+	O_2	→	O_2	+	O_2	+	O_2	2.00×10^{-25}	(19)
O_2^+	+	O_3-			→	O_2	+	O_3			2.00×10^{-07}	(19)
O_2^+	+	O_3-			→	O	+	O	+	O_3	1.00×10^{-07}	(19)
CO_3^-		CO_2^+				$2CO_2$	+	O			5.00×10^{-07}	(113)
CO_4^-		CO_2^+				$2CO_2$	+	O_2			5.00×10^{-07}	(113)
O_2-		CO_2^+				CO	+	O_2	+	O	6.00×10^{-07}	(113)

CO_3^-		$C_2O_2^+$				CO_2	+	2CO	+	O	5.00×10^{-07}	(113)
CO_4^-		$C_2O_2^+$				CO_2	+	2CO	+	O_2	5.00×10^{-07}	(113)
O_2-		$C_2O_2^+$				CO	+	CO	+	O_2	6.00×10^{-07}	(113)
CO_3^-		$C_2O_3^+$				$2CO_2$	+	CO	+	O	5.00×10^{-07}	(113)
CO_4^-		$C_2O_3^+$				$2CO_2$	+	CO	+	O_2	5.00×10^{-07}	(113)
O_2-		$C_2O_3^+$				CO_2	+	CO	+	O_2	6.00×10^{-07}	(113)
CO_3^-		$C_2O_4^+$				$3CO_2$	+	O			5.00×10^{-07}	(113)
CO_4^-		$C_2O_4^+$				$3CO_2$	+	O_2			5.00×10^{-07}	(113)
O_2-		$C_2O_4^+$				$2CO_2$	+	O_2			6.00×10^{-07}	(113)
CO_3^-		O_2^+				CO_2	+	O	+	O_2	3.00×10^{-07}	(113)
CO_4^-		O_2^+				CO_2	+	$2O_2$			3.00×10^{-07}	(113)
O_3^-	+	N^+	+	M	→	O_3	+	N			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
O_3^-	+	N_2^+	+	M	→	O_3	+	N_2			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
O_3^-	+	O^+	+	M	→	O_3	+	O			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
O_3^-	+	O_2^+	+	M	→	O_3	+	O_2			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
O_3^-	+	NO^+	+	M	→	O_3	+	NO			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
O_3^-	+	N_2O^+	+	M	→	O_3	+	N_2O			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
O_3^-	+	NO_2^+	+	M	→	O_3	+	NO_2			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)

NO^-	+	N^+	+	M	→	NO	+	N		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO^-	+	N_2^+	+	M	→	NO	+	N_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO^-	+	O^+	+	M	→	NO	+	O		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO^-	+	O_2^+	+	M	→	NO	+	O_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO^-	+	NO^+	+	M	→	NO	+	NO		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO^-	+	N_2O^+	+	M	→	NO	+	N_2O		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO^-	+	NO_2^+	+	M	→	NO	+	NO_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
N_2O^-	+	N^+	+	M	→	N_2O	+	N		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
N_2O^-	+	N_2^+	+	M	→	N_2O	+	N_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
N_2O^-	+	O^+	+	M	→	N_2O	+	O		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
N_2O^-	+	O_2^+	+	M	→	N_2O	+	O_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
N_2O^-	+	NO^+	+	M	→	N_2O	+	NO		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
N_2O^-	+	N_2O^+	+	M	→	N_2O	+	N_2O		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)

N_2O^-	+	NO_2^+	+	M	→	N_2O	+	NO_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_2^-	+	N^+	+	M	→	NO_2	+	N		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_2^-	+	N_2^+	+	M	→	NO_2	+	N_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_2^-	+	O^+	+	M	→	NO_2	+	O		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_2^-	+	O_2^+	+	M	→	NO_2	+	O_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_2^-	+	NO^+	+	M	→	NO_2	+	NO		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_2^-	+	N_2O^+	+	M	→	NO_2	+	N_2O		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_2^-	+	NO_2^+	+	M	→	NO_2	+	NO_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_3^-	+	N^+	+	M	→	NO_3	+	N		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_3^-	+	N_2^+	+	M	→	NO_3	+	N_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_3^-	+	O^+	+	M	→	NO_3	+	O		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_3^-	+	O_2^+	+	M	→	NO_3	+	O_2		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_3^-	+	NO^+	+	M	→	NO_3	+	NO		$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)

NO_3^-	+	N_2O^+	+	M	→	NO_3	+	N_2O			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
NO_3^-	+	NO_2^+	+	M	→	NO_3	+	NO_2			$2.00 \times 10^{-25}(T_{ionN2}/300)^{-2.50}$	(53)
H^-	+	H_3^+			→	H_2	+	2H			1.00×10^{-07}	(31)
H^-	+	H_2^+			→	H_2	+	H			$2.00 \times 10^{-7}(T_g/300)^{-0.50}$	(31)
H^-	+	H_2^+			→	3H					1.00×10^{-07}	(31)
H^-	+	H_2^+	+	M	→	H_2	+	H	+	M	$2.00 \times 10^{-25}(T_g/300)^{-2.50}$	(31)
H^-	+	H^+			→	H	+	H			$2.00 \times 10^{-7}(T_g/300)^{-0.50}$	(31)
H^-	+	H^+	+	M	→	H	+	H	+	M	$2.00 \times 10^{-25}(T_g/300)^{-2.50}$	(31)
H^-	+	C^+			→	H	+	C			1.00×10^{-07}	(31)
H^+	+	O^-			→	H	+	O			1.93×10^{-07}	(31)
H^+	+	O_2^-			→	H	+	O_2			1.93×10^{-07}	(31)
H^+	+	O_2^-			→	H	+	2O			1.00×10^{-07}	(31)
H^+	+	CO_3^-			→	H	+	CO_2	+	O	1.00×10^{-07}	(31)
H^+	+	CO_4^-			→	H	+	CO_2	+	O_2	1.00×10^{-07}	(31)
H^+	+	OH^-			→	H	+	OH			1.93×10^{-07}	(31)
H^+	+	OH^-			→	2H	+	O			1.00×10^{-07}	(31)
H^-	+	O_2^+			→	H	+	O_2			1.93×10^{-07}	(31)
H^-	+	O_2^+			→	H	+	2O			1.00×10^{-07}	(31)
H^-	+	CO^+			→	H	+	CO			1.93×10^{-07}	(31)

H^-	+	CO_2^+	→	H	+	O_2			1.93×10^{-07}	(31)
H^-	+	CO_2^+	→	H	+	CO	+	O	1.00×10^{-07}	(31)
H^-	+	OH^+	→	H	+	OH			1.93×10^{-07}	(31)
H^-	+	OH^+	→	2H	+	O			1.00×10^{-07}	(31)
H^-	+	H_2O^+	→	H	+	H_2O			1.93×10^{-07}	(31)
H^-	+	H_2O^+	→	2H	+	OH			1.00×10^{-07}	(31)
H_3^+	+	O^-	→	2H	+	O			1.93×10^{-07}	(31)
H_2^+	+	O^-	→	H_2	+	O			1.00×10^{-07}	(31)
H_2^+	+	O_2^-	→	H_2	+	O_2			1.93×10^{-07}	(31)
H_2^+	+	O_2^-	→	2H	+	O_2			1.00×10^{-07}	(31)
H_2^+	+	O_2^-	→	H_2	+	2O			1.00×10^{-07}	(31)
H_2^+	+	O_2^-	→	2H	+	2O			1.00×10^{-07}	(31)
H_2^+	+	CO_3^-	→	H_2	+	O	+	CO_2	1.93×10^{-07}	(31)
H_2^+	+	CO_3^-	→	2H	+	O	+	CO_2	1.00×10^{-07}	(31)
H_2^+	+	CO_4^-	→	H_2	+	O_2	+	CO_2	1.93×10^{-07}	(31)
H_2^+	+	CO_4^-	→	2H	+	O_2	+	CO_2	1.00×10^{-07}	(31)
H_2^+	+	OH^-	→	H_2	+	OH			1.93×10^{-07}	(31)
H_2^+	+	OH^-	→	2H	+	OH			1.00×10^{-07}	(31)
H_2^+	+	OH^-	→	H	+	O	+	H_2	1.00×10^{-07}	(31)
H_2^+	+	OH^-	→	3H	+	O			1.00×10^{-07}	(31)
OH^+	+	O^-	→	O	+	OH			1.93×10^{-07}	(31)
OH^+	+	O^-	→	2O	+	H			1.00×10^{-07}	(31)
OH^+	+	O_2^-	→	O_2	+	OH			1.93×10^{-07}	(31)
OH^+	+	O_2^-	→	O_2	+	O	+	H	1.00×10^{-07}	(31)
OH^+	+	O_2^-	→	2O	+	OH			1.00×10^{-07}	(31)

OH^+	+	O_2^-	→	3O	+	H			1.00×10^{-07}	(31)
OH^+	+	CO_3^-	→	OH	+	O	+	CO_2	1.00×10^{-07}	(31)
OH^+	+	CO_3^-	→	H	+	2O	+	CO_2	1.00×10^{-07}	(31)
OH^+	+	CO_4^-	→	OH	+	O_2	+	CO_2	1.00×10^{-07}	(31)
OH^+	+	CO_4^-	→	O + H	+	O_2	+	CO_2	1.00×10^{-07}	(31)
OH^+	+	OH^-	→	OH	+	OH			1.93×10^{-07}	(31)
OH^+	+	OH^-	→	OH	+	O	+	H	1.00×10^{-07}	(31)
OH^+	+	OH^-	→	2O	+	2H			1.00×10^{-07}	(31)
OH^-	+	O^+	→	O	+	OH			1.93×10^{-07}	(31)
OH^-	+	O^+	→	2O	+	H			1.00×10^{-07}	(31)
OH^-	+	O_2^+	→	OH	+	O_2			1.93×10^{-07}	(31)
OH^-	+	O_2^+	→	H	+	O_2	+	O	1.00×10^{-07}	(31)
OH^-	+	O_2^+	→	2O	+	OH			1.00×10^{-07}	(31)
OH^-	+	O_2^+	→	3O	+	H			1.00×10^{-07}	(31)
OH^-	+	CO^+	→	OH	+	CO			1.93×10^{-07}	(31)
OH^-	+	CO^+	→	O	+	CO	+	H	1.00×10^{-07}	(31)
OH^-	+	CO_2^+	→	OH	+	CO_2			1.93×10^{-07}	(31)
OH^-	+	CO_2^+	→	O	+	H	+	CO_2	1.00×10^{-07}	(31)
OH^-	+	CO_2^+	→	CO	+	O	+	OH	1.00×10^{-07}	(31)
OH^-	+	CO_2^+	→	CO	+	2O	+	H	1.00×10^{-07}	(31)
OH^-	+	H_2O^+	→	OH	+	H_2O			1.93×10^{-07}	(31)
OH^-	+	H_2O^+	→	H	+	H_2O	+	O	1.00×10^{-07}	(31)
OH^-	+	H_2O^+	→	2OH	+	H			1.00×10^{-07}	(31)
OH^-	+	H_2O^+	→	OH	+	2H	+	O	1.00×10^{-07}	(31)
OH^-	+	H_3O^+	→	OH	+	H_2O	+	H	1.00×10^{-07}	(31)

OH^-	+	H_3O^+			→	O	+	H_2O	+	2H	1.00×10^{-07}	(31)
H_2O^+	+	O^-			→	O	+	H_2O			1.93×10^{-07}	(31)
H_2O^+	+	O^-			→	OH	+	H	+	O	1.00×10^{-07}	(31)
H_2O^+	+	O_2^-			→	O_2	+	H_2O			1.00×10^{-07}	(31)
H_2O^+	+	O_2^-			→	OH	+	H	+	O_2	1.00×10^{-07}	(31)
H_2O^+	+	O_2^-			→	2O	+	H_2O			1.00×10^{-07}	(31)
H_2O^+	+	O_2^-			→	OH	+	H	+	2O	1.00×10^{-07}	(31)
H_2O^+	+	CO_3^-			→	O	+	H_2O	+	CO_2	1.00×10^{-07}	(31)
H_2O^+	+	CO_3^-			→	OH + O	+	H	+	CO_2	1.00×10^{-07}	(31)
H_2O^+	+	CO_4^-			→	O_2	+	H_2O	+	CO_2	1.00×10^{-07}	(31)
H_2O^+	+	CO_4^-			→	OH + H	+	O_2	+	CO_2	1.00×10^{-07}	(31)
H_3O^+	+	O^-			→	H	+	H_2O	+	O	1.00×10^{-07}	(31)
H_3O^+	+	O_2^-			→	H	+	H_2O	+	O_2	1.00×10^{-07}	(31)
H_3O^+	+	O_2^-			→	H	+	H_2O	+	2O	1.00×10^{-07}	(31)
H_3O^+	+	CO_3^-			→	O + H	+	H_2O	+	CO_2	1.00×10^{-07}	(31)
H_3O^+	+	CO_4^-			→	O_2 + H	+	H_2O			1.00×10^{-07}	(31)
H_3^+	+	O^-			→	H	+	H_2	+	O	1.00×10^{-07}	(31)
H_3^+	+	O_2^-			→	H	+	H_2	+	O_2	1.00×10^{-07}	(31)
H_3^+	+	O_3^-			→	H	+	H_2	+	O_3	1.00×10^{-07}	(31)
H_3^+	+	O_3^-			→	H + O	+	H_2	+	O_2	1.00×10^{-07}	(31)
H_3^+	+	O_3^-	+	M	→	H + M	+	H_2	+	O_3	1.66×10^{-24}	(31)
H_3^+	+	OH^-			→	OH	+	H	+	H_2	1.00×10^{-07}	(31)
H_3^+	+	OH^-			→	O	+	2H	+	H_2	1.00×10^{-07}	(31)
H^-	+	N^+			→	N	+	H			$2.00 \times 10^{-7}(T_g/300)^{-0.50}$	(31)

H^-	+	N^+	+	M	→	NH	+	M			$2.00 \times 10^{-25}(T_g/300)^{-2.50}$	(31)
H^-	+	N_2^+			→	N_2	+	H			$2.00 \times 10^{-7}(T_g/300)^{-0.50}$	(31)
H^-	+	N_2^+			→	2N	+	H			1.00×10^{-07}	(31)
H^-	+	N_2^+	+	M	→	N_2	+	H	+	M	$2.00 \times 10^{-25}(T_g/300)^{-2.50}$	(31)
H^-	+	N_3^+			→	N_2	+	H	+	N	1.00×10^{-07}	(31)
H^-	+	N_4^+			→	$2N_2$	+	H			1.00×10^{-07}	(31)

3 UNDERLYING MECHANISMS OF PLASMA-BASED CO_2 AND CH_4 CONVERSION

3.1 CO_2 Conversion

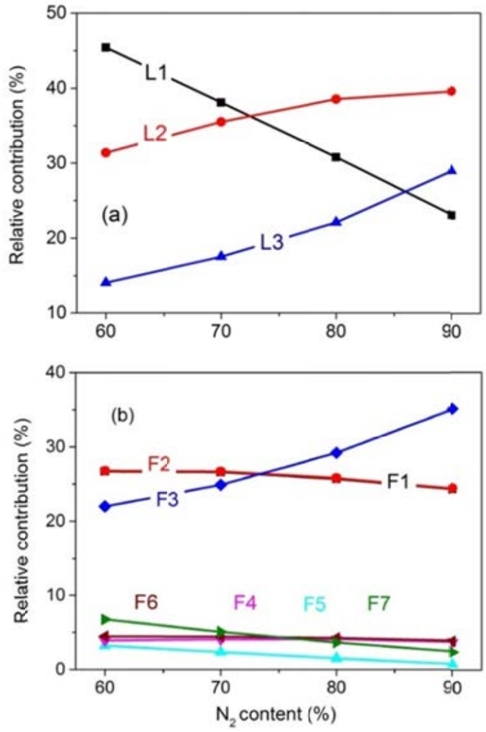

Figure S1. Relative contributions of the main processes leading to CO_2 loss (a) and formation (b) in a CO_2/CH_4/N_2 mixture, as a function of N_2 content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The N_2 content was varied with the remainder being CO_2 and CH_4.

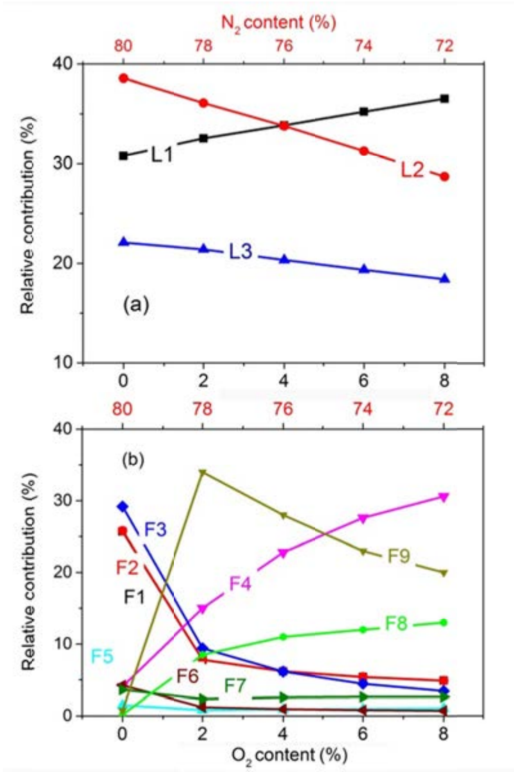

Figure S2. Relative contributions of the main processes leading to CO_2 loss (a) and formation (b) in a CO_2/CH_4/N_2/O_2 mixture, as a function of O_2 (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 %, with the remainder being O_2 and N_2.

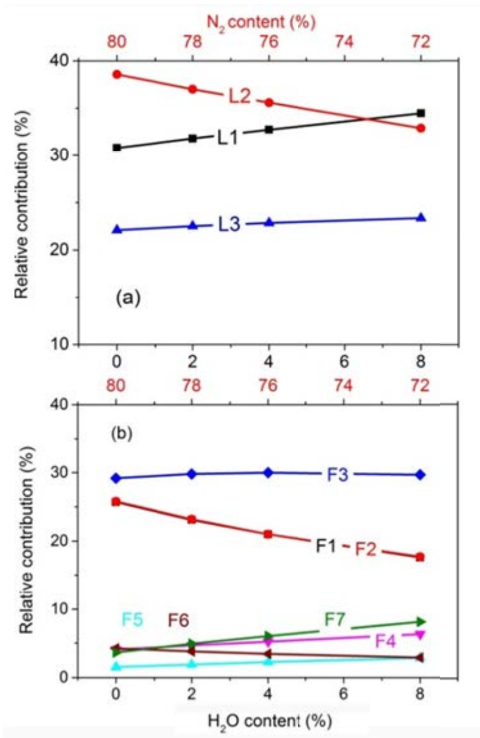

Figure S3. Relative contributions of the main processes leading to CO_2 loss (a) and formation (b) in a $CO_2/CH_4/N_2/H_2O$ mixture, as a function of H_2O (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 % with the remainder being H_2O and N_2.

3.2 CH_4 Conversion

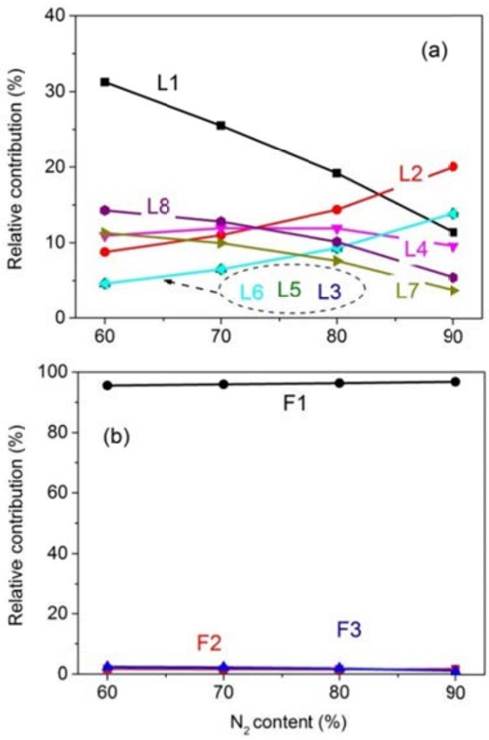

Figure S4. Relative contributions of the main processes leading to CH_4 loss (a) and formation (b) in a $CO_2/CH_4/N_2$ mixture, as a function of N_2 content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The N_2 content was varied with the remainder being CO_2 and CH_4.

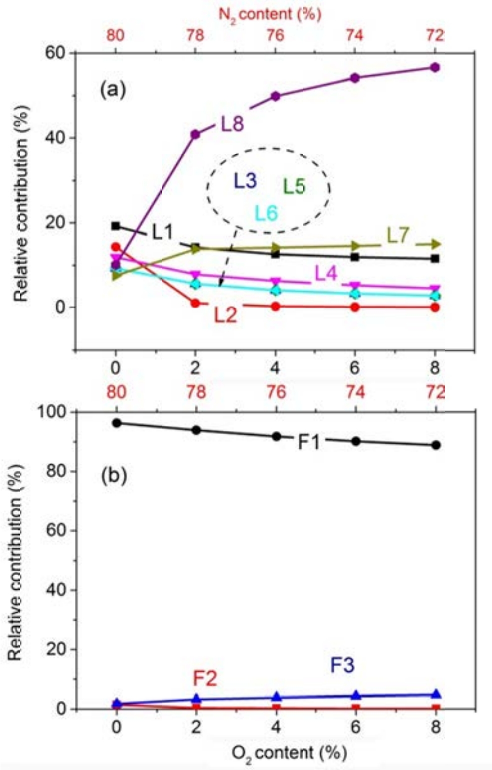

Figure S5. Relative contributions of the main processes leading to CH_4 loss (a) and formation (b) in a CO_2/CH_4/N_2/O_2 mixture, as a function of O_2 (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 %, with the remainder being O_2 and N_2.

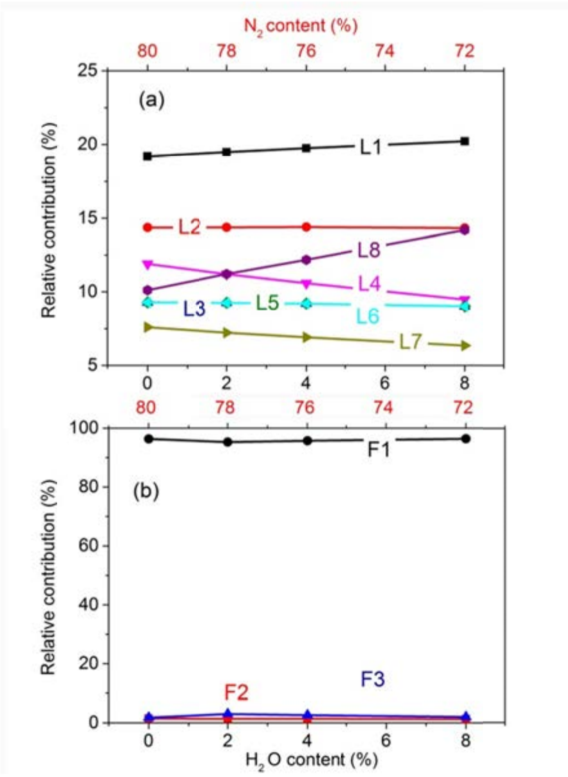

Figure S6. Relative contributions of the main processes leading to CH_4 loss (a) and formation (b) in a $CO_2/CH_4/N_2/H_2O$ mixture, as a function of H_2O (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 % with the remainder being H_2O and N_2.

3.3 CO Production

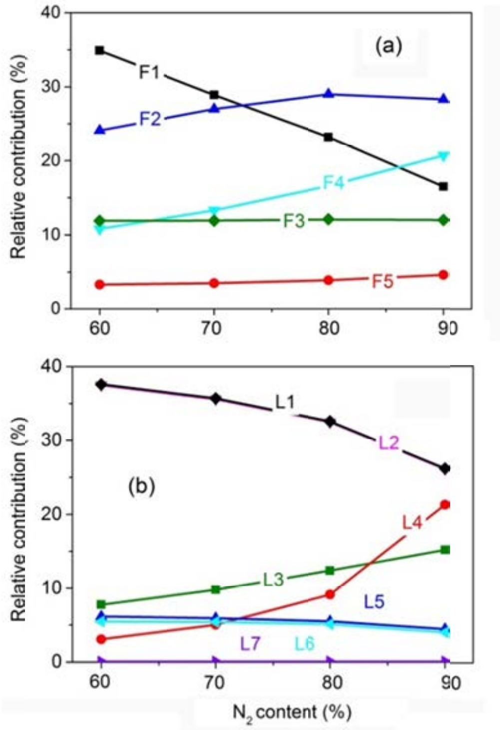

Figure S7. Relative contributions of the main processes leading to CO formation (a) and loss (b) in a $CO_2/CH_4/N_2$ mixture, as a function of N_2 content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The N_2 content was varied with the remainder being CO_2 and CH_4.

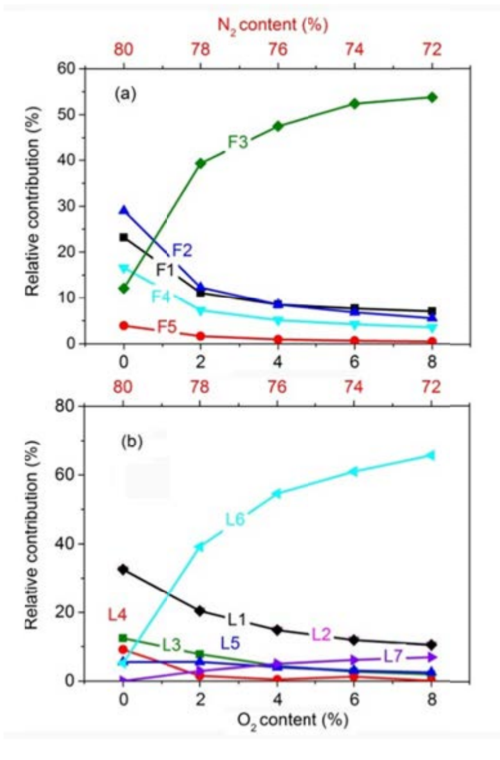

Figure S8. Relative contributions of the main processes leading to CO formation (a) and loss (b) in a $CO_2/CH_4/N_2/O_2$ mixture, as a function of O_2 (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 %, with the remainder being O_2 and N_2

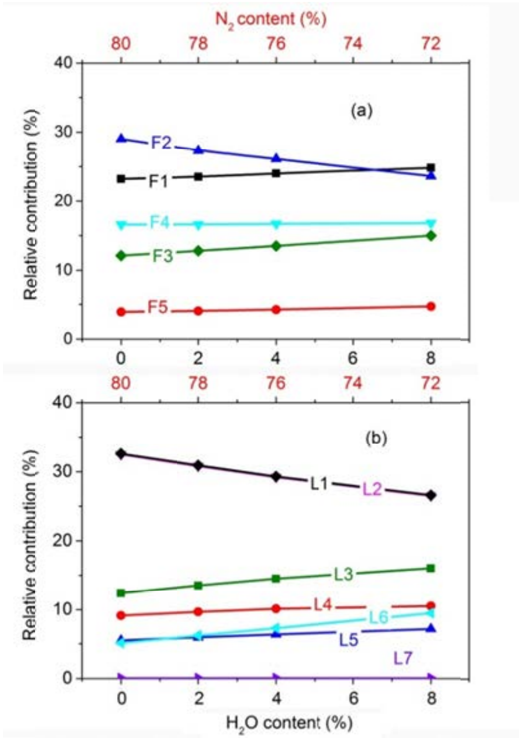

Figure S9. Relative contributions of the main processes leading to CO formation (a) and loss (b) in a $CO_2/CH_4/N_2/H_2O$ mixture, as a function of H_2O (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 % with the remainder being H_2O and N_2.

3.4 H_2 Production

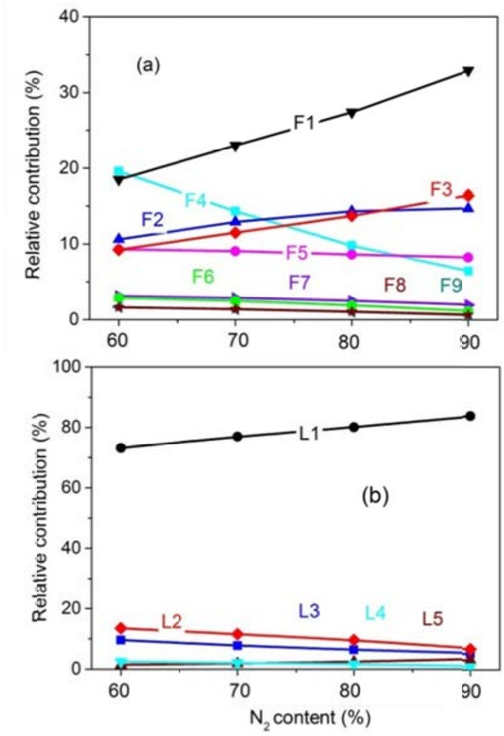

Figure S10. Relative contributions of the main processes leading to H_2 formation (a) and loss (b) in a $CO_2/CH_4/N_2$ mixture, as a function of N_2 content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The N_2 content was varied with the remainder being CO_2 and CH_4.

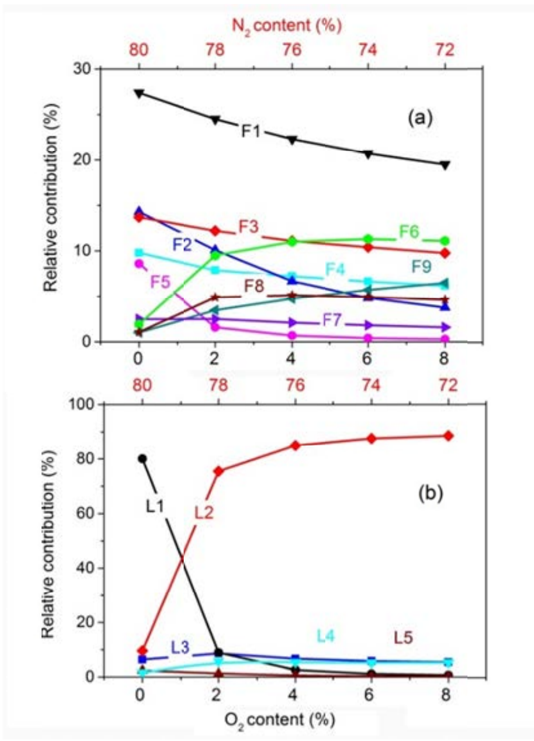

Figure S11. Relative contributions of the main processes leading to H_2 formation (a) and loss (b) in a

$CO_2/CH_4/N_2/O_2$ mixture, as a function of O_2 (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 %, with the remainder being O_2 and N_2.

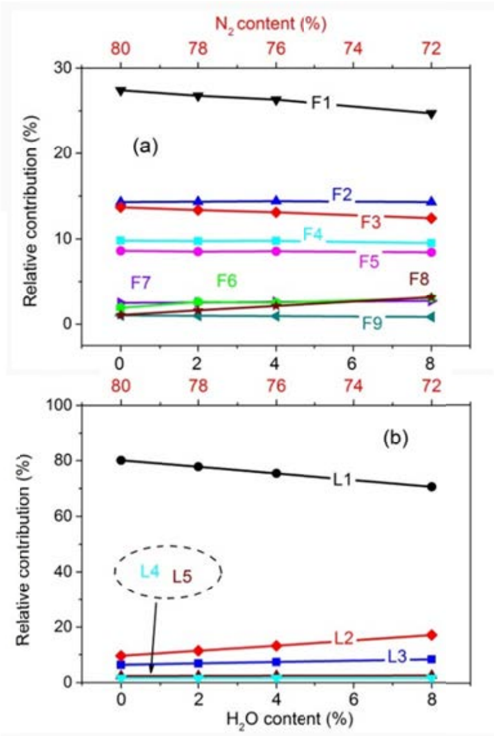

Figure S12. Relative contributions of the main processes leading to H_2 formation (a) and loss (b) in a $CO_2/CH_4/N_2/H_2O$ mixture, as a function of H_2O (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 % with the remainder being H_2O and N_2.

3.5 C_2H_6 Production

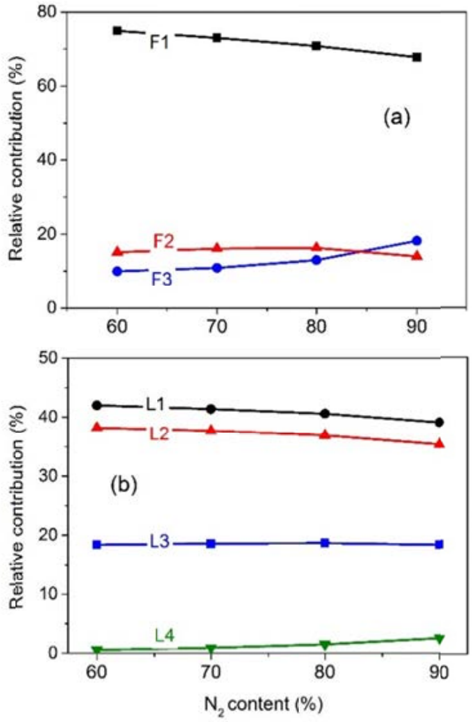

Figure S13. Relative contributions of the main processes leading to C_2H_6 formation (a) and loss (b) in a $CO_2/CH_4/N_2$ mixture, as a function of N_2 content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The N_2 content was varied with the remainder being CO_2 and CH_4.

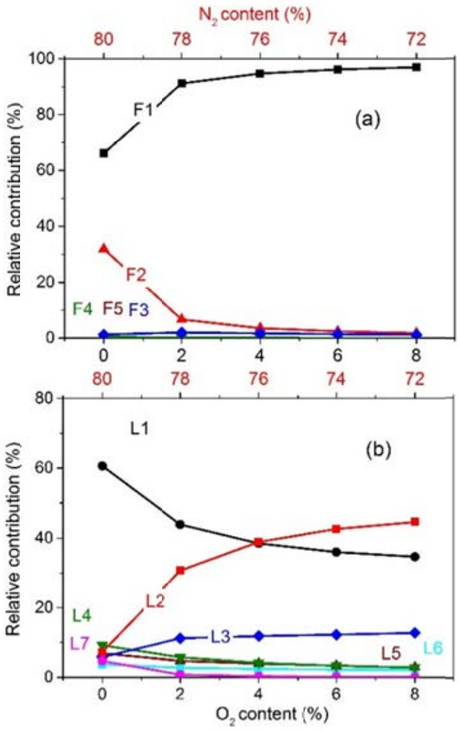

Figure S14. Relative contributions of the main processes leading to C_2H_6 formation (a) and loss (b) in a $CO_2/CH_4/N_2/O_2$ mixture, as a function of O_2 (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 % with the remainder being O_2 and N_2.

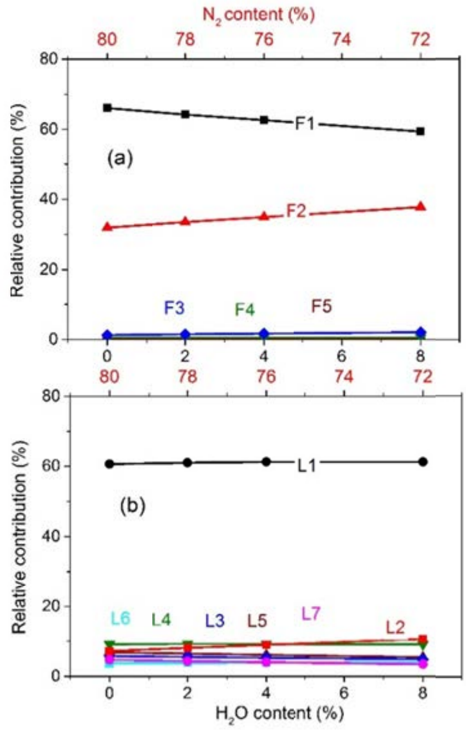

Figure S15. Relative contributions of the main processes leading to C_2H_6 formation (a) and loss (b) in a $CO_2/CH_4/N_2/H_2O$ mixture, as a function of H_2O (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 % with the remainder being H_2O and N_2.

3.6 C_3H_8 Production

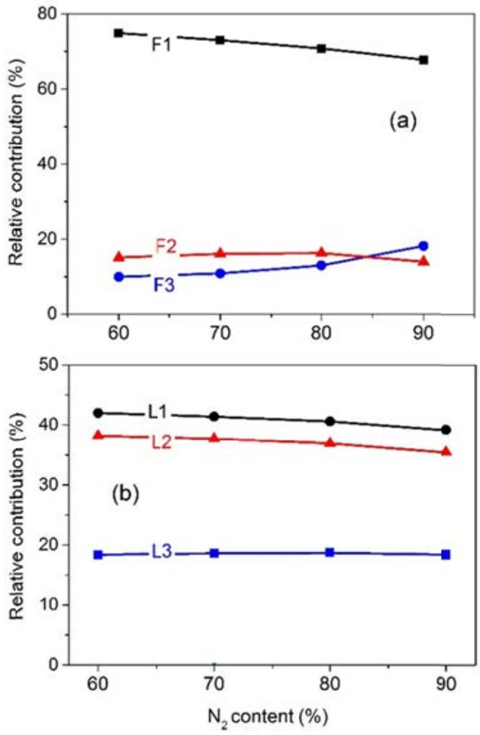

Figure S16. Relative contributions of the main processes leading to C_3H_8 loss (a) and formation (b) in a $CO_2/CH_4/N_2$ mixture, as a function of N_2 content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The N_2 content was varied with the remainder being CO_2 and CH_4.

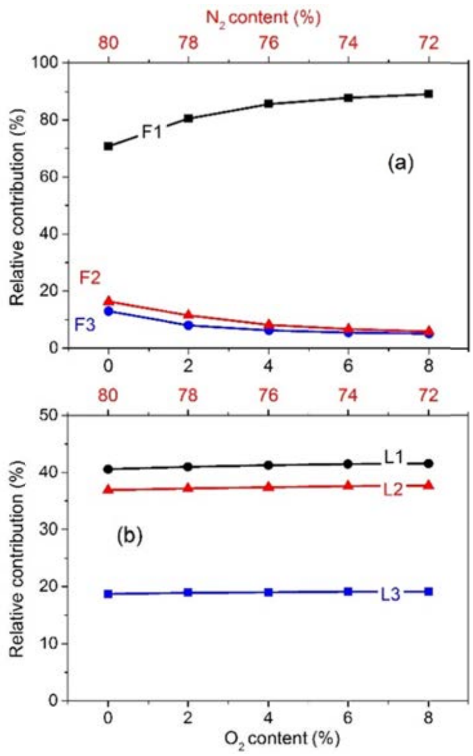

Figure S17. Relative contributions of the main processes leading to C_3H_8 loss (a) and formation (b) in a $CO_2/CH_4/N_2/O_2$ mixture, as a function of O_2 (and N_2) content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 %, with the remainder being O_2 and N_2.

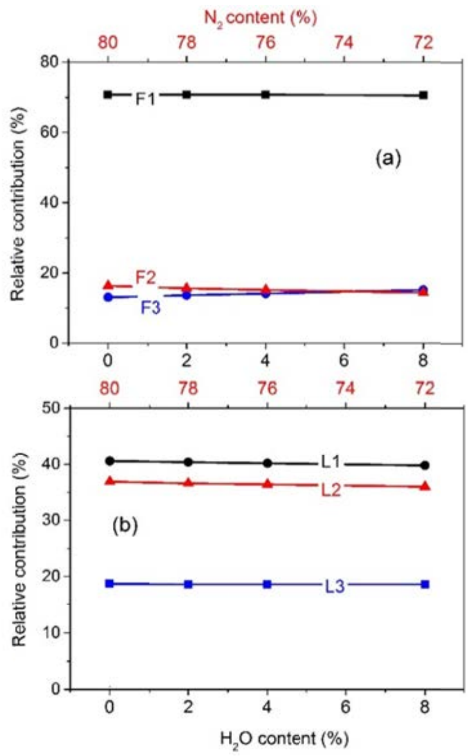

Figure S18. Relative contributions of the main processes leading to C_3H_8 loss (a) and formation (b) in a $CO_2/CH_4/N_2/H_2O$ mixture, as a function of H_2O content, for a 1:1 CO_2/CH_4 ratio, a fixed total flow rate of 200 ml/min and a corresponding SEI of 0.76 eV/molecule. The CO_2 and CH_4 content were both 10 % with the remainder being H_2O and N_2.

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