Supporting information

Plasma-assisted dry reforming of CH_4: How small amounts of O_2 addition can drastically enhance the oxygenates production - Experiments and insights from plasma chemical kinetics modelling

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S.1. Ternary flammability diagram for CO_2-CH_4-O_2 mixtures

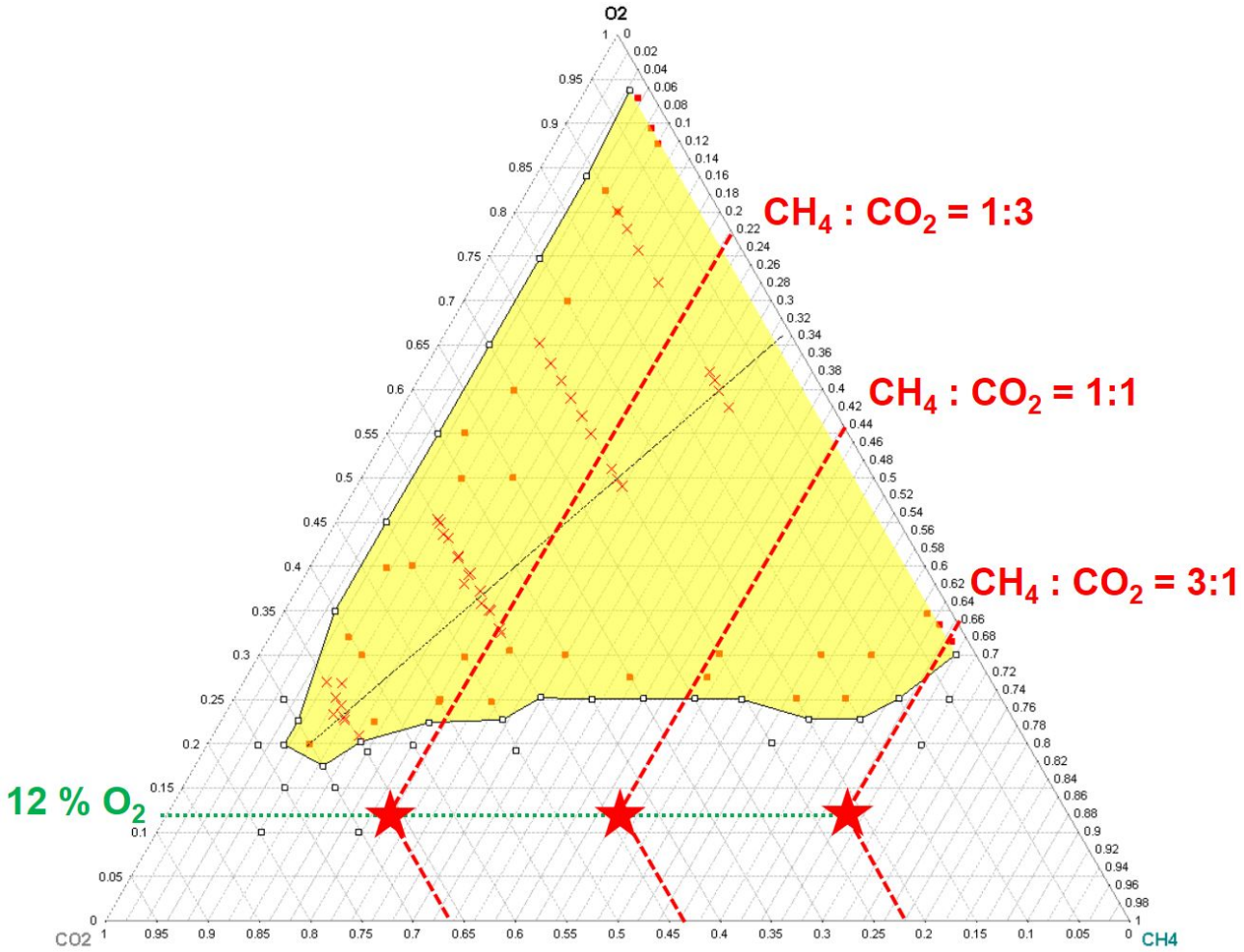

Figure S1: Ternary flammability diagram for CO_2-CH_4-O_2 mixtures, experimentally obtained by Janes et al. at 1 bar.[1] The yellow area represents flammable mixtures. The orange points label the compositions where an explosion was observed, whereas the white points represent the compositions for which no explosion took place. The right straight line indicates stoichiometric CH_4/O_2 mixtures. The large orange stars indicate the compositions used in our experiments.

As shown on Figure S1, the feed gas of $CO_2/CH_4/O_2$ was operated in the safe range, which is important to make sure it is safe without plasma. After plasma ignition, H_2 can be produced but the concentration of produced H_2 in the DBD plasma is less than 2 %, while the H_2 explosion limit in the air is 4% - 74%. We put the DBD reactor inside a Faraday cage within the fume hood in case of a leak.

S.2. Results of qualitative analysis of liquid products by HPLC

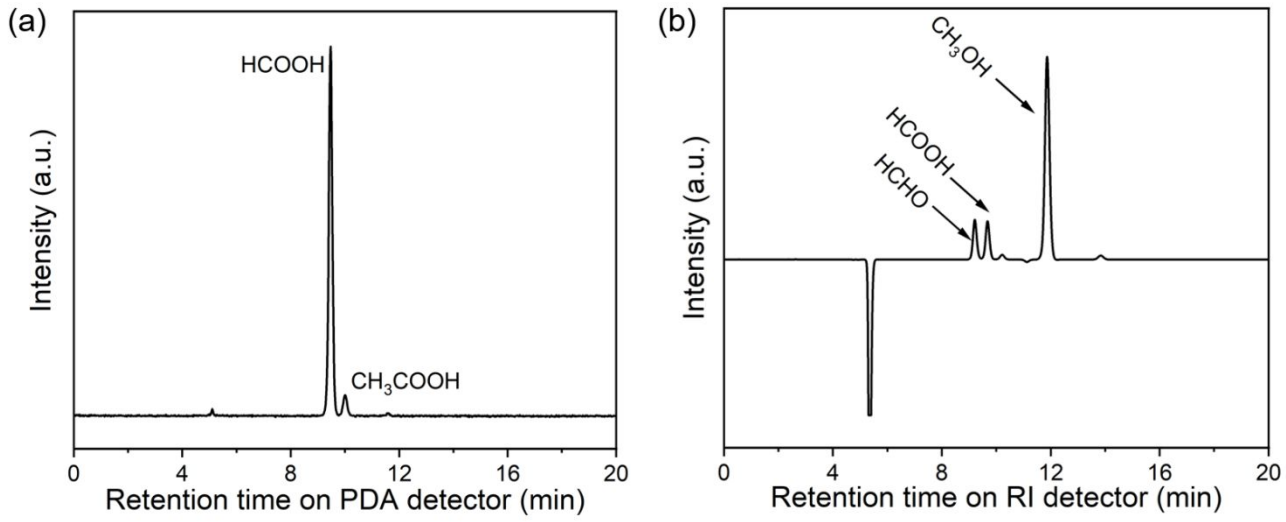

Figure S2. Results of qualitative analysis of liquid products by HPLC. (A) Photo-diode array (PDA) detector, indicating the presence of HCOOH and CH_3COOH. (B). Refractive index (RI) detector, indicating the presence of HCHO, HCOOH and CH_3OH

S.3. Calculation of conversion, selectivity, and the contraction factor

In this study, the gas flow rate ($V_{intlet/outlet}$) before and after the reaction was detected by a bubble flow meter, to account for gas expansion or contraction due to the reaction, which is crucial for correct determination of the conversion, as mentioned in the main paper. The conversion of CO_2, CH_4 and O_2, as well as the selectivity of the main gaseous products (i.e., CO, H_2, hydrocarbons (C_xH_y) and liquid products ($C_xH_yO_z$, including CH_3OH, HCHO, HCOOH and other oxygenates) was calculated by equations (S1) - (S8).

$$X_{CO_2} = \frac{C\_outlet_{CO_2} \times V_{outlet}}{C\_inlet_{CO_2} \times V_{inlet}} \times 100\% \quad \text{(S1)}$$

$$X_{CH_4} = \frac{C\_outlet_{CH_4} \times V_{outlet}}{C\_inlet_{CH_4} \times V_{inlet}} \times 100\% \quad \text{(S2)}$$

$$X_{O_2} = \frac{C\_outlet_{O_2} \times V_{outlet}}{C\_inlet_{O_2} \times V_{inlet}} \times 100\% \quad \text{(S3)}$$

$$S_{CO} = \frac{C\_outlet_{CO} \times V_{outlet}}{\left(C\_inlet_{CO_2} + C\_inlet_{CH_4}\right) \times V_{inlet} - \left(C\_outlet_{CO_2} + C\_outlet_{CH_4}\right) \times V_{outlet}} \times 100\% \quad \text{(S4)}$$

$$S_{H_2} = \frac{C\_outlet_{H_2} \times V_{outlet}}{2 \times \left(C\_inlet_{CH_4} \times V_{inlet} - C\_outlet_{CH_4} \times V_{outlet}\right)} \times 100\% \quad \text{(S5)}$$

$$S_{C_xH_y} = \frac{x \times C\_outlet_{C_xH_y} \times V_{outlet}}{\left(C\_inlet_{CO_2} + C\_inlet_{CH_4}\right) \times V_{inlet} - \left(C\_outlet_{CO_2} + C\_outlet_{CH_4}\right) \times V_{outlet}} \times 100\% \quad \text{(S6)}$$

$$S_{C_xH_yO_z,total} = 100\% - \left(S_{CO} + S_{C_xH_y}\right) \quad \text{(S7)}$$

$$S_{C_xH_yO_z} = \frac{x \times \text{mol of } C_xH_yO_z \text{ produced}}{\sum x \times C_xH_yO_z \text{ produced}} \times S_{C_xH_yO_z,total} \quad \text{(S8)}$$

Note that equation (S7) is only valid when the amount of coking is negligible, which is the case in our experiments (certainly when adding O_2).

Additionally, we estimate the H_2O formation based on the hydrogen balance (S9):

$$S_{H_2O} = 100\% - (S_{C_xH_y} + S_{C_xH_yO_z} + S_{H_2}) \quad \text{(S9)}$$

The specific energy input (SEI) is defined as:

$$\text{SEI}(\text{kJ/L}) = \frac{\text{discharge power}(\text{J/s})}{\text{feed gas flow rate}(\text{L/min})} \times \frac{60(\text{s/min})}{1000(\text{J/kJ})} \quad \text{(S10)}$$

The total conversion is defined as the weighted average of the conversion for each reactant, weighted over their concentration in the inlet gas mixture:

$$X^{total} = \sum_i c_i X_i \quad \text{(S11)}$$

The total energy cost (S12) is expressed in terms of the total conversion and the specific

energy input (SEI, kJ/L). Note that equation (S12) can also be expressed in terms of eV/molecule (S13):

$$EC(kJ/L) = \frac{SEI\ (kJ/L)}{X^{total}\ (\%)} \times 100\% \quad \text{(S12)}$$

Finally, as mentioned above, the stoichiometry of chemical reactions leads to a change of the total volume of the gas exiting the reactor, indicated by the bubble flow meter. Therefore, in order to evaluate the volume change of the outlet gas flow, i.e., expansion/contraction, we define the contraction factor (V_c) based on volume change before and after plasma ignition.

$$V_C = \left(1 - \frac{V_{outlet}}{V_{inlet}}\right) \times 100\% \quad \text{(S13)}$$

S.4. Description of the chemical kinetics model

Unlike the rate coefficients for reactions between heavy particles, which can be directly obtained from literature, the rate coefficients for electron impact reactions are usually calculated by solving the Boltzmann equation with BOLSIG+, based on the cross-section data, as shown in Eq. (S11)

$$k_k = r\int_0^\infty \varepsilon\sigma_k f_0 d\varepsilon \tag{S14}$$

where $\gamma=(2e/m_e)^{1/2}$ is constant (in $C^{1/2}$ $kg^{-1/2}$), e and m_e are the elementary charge ($1.6021766208\times10^{-19}$ C) and electron mass (9.10956×10^{-31} kg), respectively. ε is the electron energy, σ_k is the cross section of the various electron-neutral collision processes k, and f_0 is the electron energy distribution function (EEDF).

The AC power supply activates the DBD, which typically exhibits filamentary behavior at atmospheric pressure in our experiments and other work.[2] An improved and detailed method that more systematically translates the experimental conditions and observations to an equivalent 0D model was used in our study, and the detailed description of the model can be found in previous works from our group.[3,4]

The electric field E, at which BOLSIG+ solves the Boltzmann equation, is calculated using the differential from of the Joule heating equation

$$\frac{\mathrm{d}P}{\mathrm{d}V} = \mathbf{J}\cdot\mathbf{E} = \sigma E^2 \tag{S15}$$

where P is the power and dV a volume element, $\mathbf{J} = \sigma\mathbf{E}$ is the current density and σ is the electron conductivity. Assuming no spatial dependence, the reduced electric field (E/N) can be calculated from the power density $p\equiv P/V$ as

$$\left(\frac{E}{N}\right) = \frac{1}{N}\sqrt{\frac{p}{\sigma}} \tag{S16}$$

where N is the number density of neutral species. The electron conductivity σ is calculated by

$$\sigma = en_e\mu_e \tag{S17}$$

where n_e is the electron number density and μ_e the electron mobility, calculated by BOLSIG+.

S.5. Fraction of electron energy into different excitation channels

The detailed plasma parameters of our model are listed in the Table S1. The reduced electric field (i.e., the ratio of electric field over total gas number density, *E*/*N*) is one of the most important parameters in controlling the distribution of the electron energy deposition to different excitation modes and to the formation of active species in a non-equilibrium plasma. It is expressed in Td, where 1 Td = 10^{-17} V cm^2. Figure S3 shows the fraction of electron energy deposited into different excitation channels in a (a) 1:1 CH_4/CO_2 mixture and (b) 1:1 CH_4/CO_2 mixture with 12% O_2 addition, as a function of *E*/*N*. The electron energy loss fractions were calculated by the BOLSIG+ solver.[5] The regions in blue indicate the range of *E*/*N* values of the discharge conditions solved in our chemical kinetics model. As shown in Figure S3(a), the most efficient mechanism for electron energy loss is the elastic collision with CH_4 and CO_2 molecules and the dissociation of CH_4 at a relatively low reduced electric field (< 20 Td). In our model, the *E*/*N* ranges from several 100 Td (during the microdischarges) to a few Td (during the afterglows in between the microdischarges), so if we take a time-average, we get a range of 20-100 Td, for which the dissociation channel of CH_4 dominates the plasma discharge. The change of mixture ratio upon 12% O_2 addition dramatically alters the energy branching, and the plasma energy is now primarily transferred to the dissociation modes of CH_4 and O_2, as shown in Figure S3(b). As a result, the addition of O_2 to the CH_4/CO_2 mixture promotes the dissociation of O_2 to produce O and O(^{1}D) radicals, which facilitates the oxidation of CH_4 to oxygenates.

Table S1. Plasma parameters in the model

Condition	peak power density (W/cm^3)	duration (ns)	$n_{e,max}$ (cm^{-3})	$T_{e,max}$ (eV)	$E/N_{,max}$ (Td)
0.50 CH_4/0.50 CO_2	2.13×10^5	200	2.40×10^{13}	4.32	242
0.44 CH_4/0.44 CO_2/0.12 O_2	2.78×10^5	200	1.05×10^{13}	6.29	571

($n_{e,max}$: maximum electron density; $T_{e,max}$: maximum electron temperature; $E/N_{,max}$: maximum electron temperature)

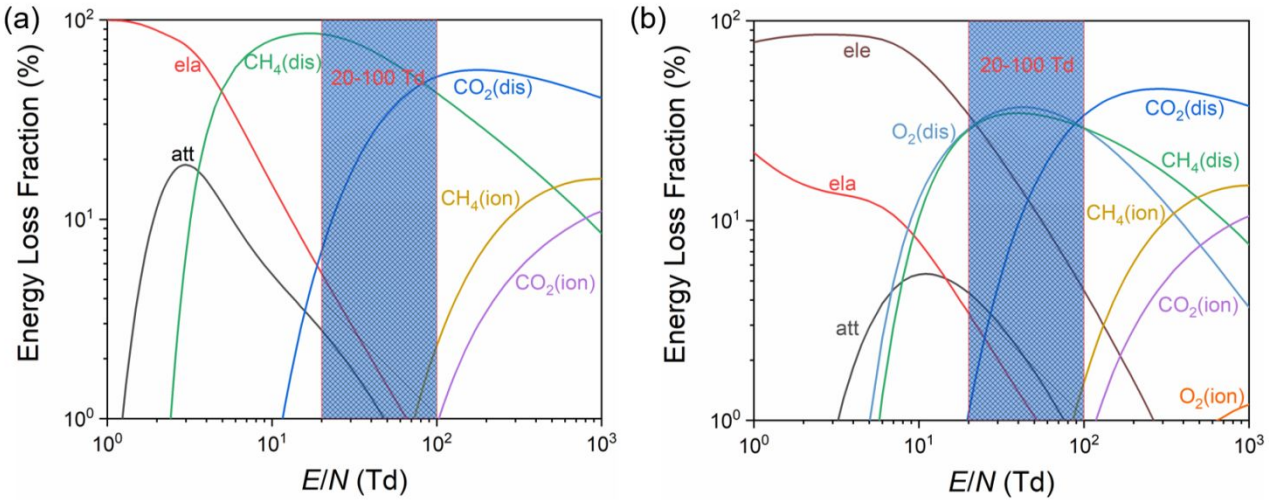

Figure S3. Fractions of electron energy deposited into different excitation modes in a (a) 1:1 CH_4/CO_2, and (b) 1:1 CH_4/CO_2/ mixture with 12% O_2, as a function of *E*/*N* (att: attachment; ela: elastic; ele: electronic excitation; dis: dissociation; ion: ionization).

S.6. Reaction pathway analysis for the most important oxygenates in a 1:1 CO_2-CH_4 mixture

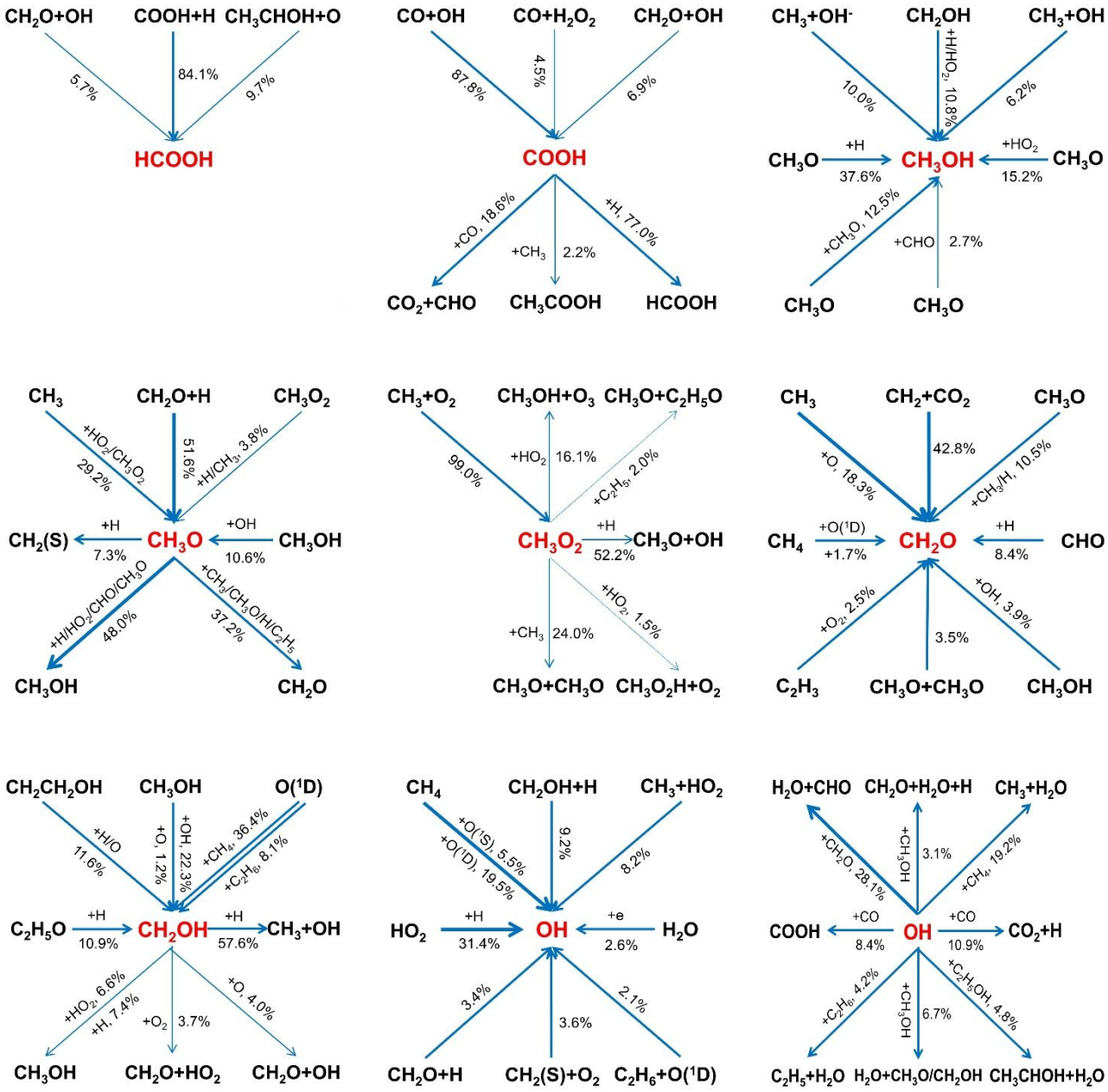

Figure S4. Reaction pathway analysis for HCOOH, COOH, CH_3OH, CH_3O, CH_3O_2, CH_2O, CH_2OH and OH for a 1:1 CH_4/CO_2 discharge mixture without O_2, at atmospheric pressure, at a PSU power of 40 W, a residence time of 6.78 s, and temperature of 35 °C. Note that for OH, for the sake of clarity, the analysis is split in formation reactions and consumption reactions, due to the many reactions taking place.

S.7. The consumption pathways of CO_2 and O_2 for the 1:1 CH_4/CO_2 mixture with or without O_2 addition (Table R1-R4)

The consumption pathways of CO_2 and O_2 for the 1:1 CH_4/CO_2 mixture with or without O_2 addition are listed in Table R1-R4. As can be seen, the main competing reaction of CO_2 and O_2 is the electron impact reaction for plasma energy. In addition to the electron impact reaction, there is another competing reaction of CO_2 or O_2 based on the path flux analysis, that is, $CH_2 + CO_2 \rightarrow CH_2O + CO$ and $CH_2 + O_2 \rightarrow CO + H_2O$ (COOH + H). However, this competing reaction has negligible influence on the formation of oxygenates. This further enhances the conclusion presented in the manuscript that two types of reactions are responsible for the production enhancement of oxygenated compounds upon O_2 addition.

Table R1. CO_2 consumption pathways in a 1:1 CH_4/CO_2 mixture.

Reaction	(mol/cm^3)	Contribution ratio
$e + CO_2 \rightarrow e + CO + O/O(^1D)/O(^1S)$	1.05×10^{-6}	52.4%
$e + CO_2 \rightarrow CO + O^-$	3.14×10^{-7}	15.6%
$O(^1D) + CO_2 \rightarrow CO + O_2$	3.06×10^{-7}	15.2%
$CH_2 + CO_2 \rightarrow CH_2O + CO$	2.76×10^{-7}	13.7%
$O(^1S) + CO_2 \rightarrow CO + O_2$	4.45×10^{-8}	2.2%
$CO_2^+ + CO_2 + M \rightarrow C_2O_4^+ + M$	6.68×10^{-9}	0.3%
$e + CO_2 \rightarrow CO_2^+ + 2e$	4.20×10^{-9}	0.2%

Table R2. O_2 consumption pathways in a 1:1 CH_4/CO_2 mixture.

Reaction	(mol/cm^3)	Contribution ratio
$CHO + O_2 \rightarrow CO + HO_2$	$3.17\times10-7$	59.1%
$C_2H_5 + O_2 \rightarrow C_2H_5O_2$	6.28×10^{-8}	11.7%
$H + O_2 + M \rightarrow HO_2 + M$	4.83×10^{-8}	9.0%
$CH_2(S) + O_2 \rightarrow CO + OH + H$	3.15×10^{-8}	5.9%
$C_2H_3 + O_2 \rightarrow CH_2O + CHO$	1.62×10^{-8}	3.0%
$CH_2(S) + O_2 \rightarrow CO + H_2O$	1.35×10^{-8}	2.5%

$CH_3 + O_2 \rightarrow CH_3O_2$	1.25×10^{-8}	2.3%
$e + O_2 \rightarrow e + O_2(e1)$	9.44×10^{-9}	1.8%
$CH_3CHOH + O_2 \rightarrow CH_3CHO + HO_2$	7.93×10^{-9}	1.5%
$CH_2OH + O_2 \rightarrow CH_2O + HO_2$	5.20×10^{-9}	1.0%

Table R3. CO_2 consumption pathways in a 1:1 CH_4/CO_2 mixture with 12% O_2 addition.

Reaction	(mol/cm^3)	Contribution ratio
$e + CO_2 \rightarrow e + CO + O/O(^1D)/O(^1S)$	6.77×10^{-6}	86.8%
$O(^1D) + CO_2 \rightarrow CO + O_2$	7.63×10^{-7}	9.8%
$O_3^- + CO_2 \rightarrow CO_3^- + O_2$	8.08×10^{-8}	1.0%
$O(^1S) + CO_2 \rightarrow CO + O_2$	6.45×10^{-8}	0.8%
$O_4^- + CO_2 \rightarrow CO_4^- + O_2$	3.75×10^{-8}	0.5%
$e + CO_2 \rightarrow CO + O^-$	3.17×10^{-8}	0.4%
$CH_2 + CO_2 \rightarrow CH_2O + CO$	1.75×10^{-8}	0.2%

Table R4. O_2 consumption pathways in a 1:1 CH_4/CO_2 mixture with 12% O_2 addition.

Reaction	(mol/cm^3)	Contribution ratio
$CHO + O_2 \rightarrow CO + HO_2$	6.99×10^{-6}	43.2%
$O + O_2 + M \rightarrow O_3 + M$	2.64×10^{-6}	16.3%
$e + O_2 \rightarrow e + O + O/O(^1D)$	1.45×10^{-6}	9.0%
$e + O_2 \rightarrow e + O_2(e)$	1.40×10^{-6}	8.6%
$CH_3 + O_2 \rightarrow CH_3O_2$	1.25×10^{-6}	7.8%
$H + O_2 + M \rightarrow HO_2 + M$	1.14×10^{-6}	7.0%
$CH_2OH + O_2 \rightarrow CH_2O + HO_2$	6.12×10^{-7}	3.8%
$O_2^+ + O_2 + M \rightarrow O_4^+ + M$	1.20×10^{-7}	0.7%
$CH_2 + O_2 \rightarrow CO + H_2O$	1.04×10^{-7}	0.6%
$CH_2 + O_2 \rightarrow COOH + H$	3.94×10^{-8}	0.2%

S.8. Reaction pathway analysis of singlet oxygen $O_2(a^1\Delta_g)$*.

As can be seen in Figure S5, $O_2(a^1\Delta_g)$ is primarily formed via electron impact electronic excitation, $e + O_2 \rightarrow e + O_2(a^1\Delta_g)$, which is responsible for 99.9% and 100.0% for $O_2(a^1\Delta_g)$ formation, with or without O_2 addition, respectively. However, the consumption way shows that most of the $O_2(a^1\Delta_g)$ are consumed via the relaxation reactions. Only 1.8% of $O_2(a^1\Delta_g)$ react with CH_3CHOH to form HO_2 without O_2 addition. Upon O_2 addition, 0.3% of $O_2(a^1\Delta_g)$ participate in the chain reaction to form O_3. The reaction pathway analysis demonstrates that the effects of $O_2(a^1\Delta_g)$ are negligible in this work.

*: $O_2(a^1\Delta_g)$ represents $O_2(e1)$.

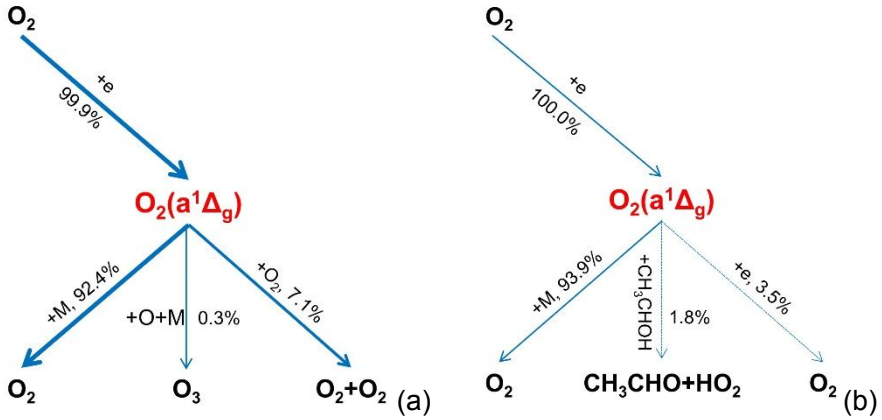

Figure S5. Reaction pathway analysis for $O_2(a^1\Delta_g)$ for a 1:1 CH_4/CO_2 mixture (a) with and (b) without 12% O_2 addition respectively. at atmospheric pressure, at a PSU power of 40 W, a residence time of 6.78 s, and temperature of 35 ℃.

S.9. Overview of the reactions included in our model (Table S2 – S12).

The units of the rate coefficients are in s^{-1}, $cm^3\ s^{-1}$ and $cm^6\ s^{-1}$ for first, second and third reactions, respectively. In the expressions of the rate constants, T_g denotes the gas temperature in K, T_e denotes the average electron temperature in K, and R denotes the ideal gas constant, 8.3145 J mol^{-1} K^{-1}.

Table S2. Electron impact attachment and dissociative attachment reactions

Reaction	Rate coefficients	Ref
$e + O + M \rightarrow O^- + M$	1.00×10^{-31}	6,7
$e + O_2 + M \rightarrow O_2^- + M$	f(σ, EEDF)[1]	8
$e + O_2 + H_2 \rightarrow O_2^- + H_2$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 + CO \rightarrow O_2^- + CO$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 + CO(e1) \rightarrow O_2^- + CO(e1)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 + CO(e2) \rightarrow O_2^- + CO(e2)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 + CO(e3) \rightarrow O_2^- + CO(e3)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 + CO(e4) \rightarrow O_2^- + CO(e4)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 + O_2(e1) \rightarrow O_2^- + O_2(e1)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 + O_2(e2) \rightarrow O_2^- + O_2(e2)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2 \rightarrow O^- + O$	f(σ, EEDF)	8
$e + O_3 \rightarrow O^- + O_2$	f(σ, EEDF)	8
$e + O_3 \rightarrow O_2^- + O$	f(σ, EEDF)	8
$e + H_2O \rightarrow O^- + H_2$	f(σ, EEDF)	8
$e + H_2O \rightarrow OH^- + H$	f(σ, EEDF)	8
$e + CO \rightarrow O^- + C$	f(σ, EEDF)	8
$e + CO_2 \rightarrow O^- + CO$	f(σ, EEDF)	8

[1]: the rate coefficients for electron impact reactions depend on the cross sections and electron energy distribution function (EEDF), and is calculated by means of a Boltzmann solver, integrated in ZDPlasKin.

Table S3. Electron impact excitation reactions

Reaction	Rate coefficients	Ref
$e + O \rightarrow e + O(^1D)$	f(σ, EEDF)	8

$e + O_2 \rightarrow e + O_2(e1)$	f(σ, EEDF)	8
$e + O_2 \rightarrow e + O_2(e2)$	f(σ, EEDF)	8
$e + O_2 \rightarrow e + O_2(e3)$	f(σ, EEDF)	8
$e + CO \rightarrow e + CO(e1)$	f(σ, EEDF)	8
$e + CO \rightarrow e + CO(e2)$	f(σ, EEDF)	8
$e + CO \rightarrow e + CO(e3)$	f(σ, EEDF)	8
$e + CO \rightarrow e + CO(e4)$	f(σ, EEDF)	8

Table S4. Electron impact dissociation reactions

Reaction	Rate coefficients	Ref
$e + H_2 \rightarrow e + H + H$	f(σ, EEDF)	8,9
$e + O_2 \rightarrow e + O + O$	f(σ, EEDF)	8
$e + O_2 \rightarrow e + O + O(^1D)$	f(σ, EEDF)	8
$e + O_3 \rightarrow e + O_2 + O$	f(σ, EEDF)	6,7
$e + H_2O \rightarrow e + OH + H$	f(σ, EEDF)	8
$e + H_2O \rightarrow e + O(^1D) + H_2$	f(σ, EEDF)	8
$e + H_2O \rightarrow e + O + H + H$	f(σ, EEDF)	8
$e + CO \rightarrow e + C + O$	f(σ, EEDF)	8
$e + CO_2 \rightarrow e + CO + O$	f(σ, EEDF)	8,10
$e + CO_2 \rightarrow e + CO + O(^1D)$	f(σ, EEDF)	8,10
$e + CO_2 \rightarrow e + CO + O(^1S)$	f(σ, EEDF)	8,10,11
$e + CH \rightarrow e + C + H$	f(σ, EEDF)	12
$e + CH_2 \rightarrow e + CH + H$	f(σ, EEDF)	12
$e + CH_2 \rightarrow e + C + H_2$	f(σ, EEDF)	12
$e + CH_2 \rightarrow e + C + H + H$	f(σ, EEDF)	12
$e + CH_3 \rightarrow e + CH_2 + H$	f(σ, EEDF)	12
$e + CH_3 \rightarrow e + CH + H_2$	f(σ, EEDF)	12
$e + CH_3 \rightarrow e + C + H_2 + H$	f(σ, EEDF)	12
$e + CH_4 \rightarrow e + CH_3 + H$	f(σ, EEDF)	6,7
$e + CH_4 \rightarrow e + CH_2 + H_2$	f(σ, EEDF)	6,7
$e + CH_4 \rightarrow e + CH + H_2 + H$	f(σ, EEDF)	6,7
$e + CH_4 \rightarrow e + C + H_2 + H_2$	f(σ, EEDF)	6,7
$e + C_2H \rightarrow e + C_2 + H$	f(σ, EEDF)	13
$e + C_2H \rightarrow e + C + CH$	f(σ, EEDF)	13

$e + C_2H_2 \rightarrow e + C_2H + H$	f(σ, EEDF)	13
$e + C_2H_2 \rightarrow e + C_2 + H_2$	f(σ, EEDF)	13
$e + C_2H_2 \rightarrow e + C_2 + H + H$	f(σ, EEDF)	13
$e + C_2H_2 \rightarrow e + CH_2 + C$	f(σ, EEDF)	13
$e + C_2H_2 \rightarrow e + CH + CH$	f(σ, EEDF)	13
$e + C_2H_3 \rightarrow e + C_2H_2 + H$	f(σ, EEDF)	13
$e + C_2H_3 \rightarrow e + C_2H + H_2$	f(σ, EEDF)	13
$e + C_2H_3 \rightarrow e + C_2H + H + H$	f(σ, EEDF)	13
$e + C_2H_3 \rightarrow e + C_2 + H_2 + H$	f(σ, EEDF)	13
$e + C_2H_3 \rightarrow e + CH_3 + C$	f(σ, EEDF)	13
$e + C_2H_3 \rightarrow e + CH_2 + CH$	f(σ, EEDF)	13
$e + C_2H_4 \rightarrow e + C_2H_3 + H$	f(σ, EEDF)	8,14
$e + C_2H_4 \rightarrow e + C_2H_2 + H_2$	f(σ, EEDF)	8,14
$e + C_2H_4 \rightarrow e + C_2H_2 + H + H$	f(σ, EEDF)	8,14
$e + C_2H_4 \rightarrow e + C_2H + H_2 + H$	f(σ, EEDF)	8,14
$e + C_2H_4 \rightarrow e + CH_4 + C$	f(σ, EEDF)	8,14
$e + C_2H_4 \rightarrow e + CH_3 + CH$	f(σ, EEDF)	8,14
$e + C_2H_4 \rightarrow e + CH_2 + CH_2$	f(σ, EEDF)	8,14
$e + C_2H_5 \rightarrow e + C_2H_4 + H$	f(σ, EEDF)	13
$e + C_2H_5 \rightarrow e + C_2H_3 + H_2$	f(σ, EEDF)	13
$e + C_2H_5 \rightarrow e + C_2H_3 + H + H$	f(σ, EEDF)	13
$e + C_2H_5 \rightarrow e + C_2H_2 + H_2 + H$	f(σ, EEDF)	13
$e + C_2H_5 \rightarrow e + C_2H + H_2 + H_2$	f(σ, EEDF)	13
$e + C_2H_5 \rightarrow e + CH_4 + CH$	f(σ, EEDF)	13
$e + C_2H_5 \rightarrow e + CH_3 + CH_2$	f(σ, EEDF)	13
$e + C_2H_6 \rightarrow e + C_2H_5 + H$	f(σ, EEDF)	8,15
$e + C_2H_6 \rightarrow e + C_2H_4 + H_2$	f(σ, EEDF)	8,15
$e + C_2H_6 \rightarrow e + C_2H_3 + H_2 + H$	f(σ, EEDF)	8,15
$e + C_2H_6 \rightarrow e + C_2H_2 + H_2 + H_2$	f(σ, EEDF)	8,15
$e + C_2H_6 \rightarrow e + CH_4 + CH_2$	f(σ, EEDF)	8,15
$e + C_2H_6 \rightarrow e + CH_3 + CH_3$	f(σ, EEDF)	8,15
$e + C_3H_5 \rightarrow e + C_2H_2 + CH_3$	f(σ, EEDF)	13
$e + C_3H_5 \rightarrow e + C_2H + CH_4$	f(σ, EEDF)	13
$e + C_3H_6 \rightarrow e + C_3H_5 + H$	f(σ, EEDF)	8,16

$e + C_3H_6 \rightarrow e + C_2H_4 + CH_2$	f(σ, EEDF)	8,16
$e + C_3H_6 \rightarrow e + C_2H_3 + CH_3$	f(σ, EEDF)	8,16
$e + C_3H_6 \rightarrow e + C_2H_2 + CH_4$	f(σ, EEDF)	8,16
$e + C_3H_7 \rightarrow e + C_3H_6 + H$	f(σ, EEDF)	13
$e + C_3H_7 \rightarrow e + C_3H_5 + H_2$	f(σ, EEDF)	13
$e + C_3H_7 \rightarrow e + C_2H_4 + CH_3$	f(σ, EEDF)	13
$e + C_3H_7 \rightarrow e + C_2H_3 + CH_4$	f(σ, EEDF)	13
$e + C_3H_8 \rightarrow e + C_3H_7 + H$	f(σ, EEDF)	8
$e + C_3H_8 \rightarrow e + C_3H_6 + H_2$	f(σ, EEDF)	8
$e + C_3H_8 \rightarrow e + C_2H_6 + CH_2$	f(σ, EEDF)	8
$e + C_3H_8 \rightarrow e + C_2H_5 + CH_3$	f(σ, EEDF)	8
$e + C_3H_8 \rightarrow e + C_2H_4 + CH_4$	f(σ, EEDF)	8

Table S5. Electron impact ionization reactions

Reaction	**Rate coefficients**	**Ref**
$e + H \rightarrow 2e + H^+$	f(σ, EEDF)	8
$e + O \rightarrow 2e + O^+$	f(σ, EEDF)	8
$e + H_2 \rightarrow 2e + H_2^+$	f(σ, EEDF)	8
$e + OH \rightarrow 2e + OH^+$	f(σ, EEDF)	6,7
$e + O_2 \rightarrow 2e + O_2^+$	f(σ, EEDF)	8
$e + O_2 \rightarrow 2e + O^+ + O$	f(σ, EEDF)	8
$e + O_3 \rightarrow 2e + O_2^+ + O$	f(σ, EEDF)	8
$e + O_3 \rightarrow e + O^+ + O^- + O$	f(σ, EEDF)	8
$e + C \rightarrow 2e + C^+$	f(σ, EEDF)	8
$e + CO \rightarrow 2e + CO^+$	f(σ, EEDF)	8
$e + CO \rightarrow 2e + C^+ + O$	f(σ, EEDF)	8
$e + CO \rightarrow 2e + O^+ + C$	f(σ, EEDF)	8
$e + CO_2 \rightarrow 2e + CO_2^+$	f(σ, EEDF)	8
$e + CO_2 \rightarrow 2e + O^+ + CO$	f(σ, EEDF)	8
$e + CO_2 \rightarrow 2e + C^+ + O_2$	f(σ, EEDF)	8
$e + CO_2 \rightarrow 2e + CO^+ + O$	f(σ, EEDF)	8
$e + CO_2 \rightarrow 2e + O_2^+ + C$	f(σ, EEDF)	8
$e + CH \rightarrow 2e + CH^+$	f(σ, EEDF)	6,7
$e + CH_2 \rightarrow 2e + CH_2^+$	f(σ, EEDF)	6,7

$e + CH_3 \rightarrow 2e + CH_3^+$	f(σ, EEDF)	6,7
$e + CH_3 \rightarrow 2e + CH_2^+ + H$	f(σ, EEDF)	6,7
$e + CH_3 \rightarrow 2e + CH^+ + H_2$	f(σ, EEDF)	6,7
$e + CH_4 \rightarrow 2e + CH_4^+$	f(σ, EEDF)	6,7
$e + CH_4 \rightarrow 2e + CH_3^+ + H$	f(σ, EEDF)	6,7
$e + CH_4 \rightarrow 2e + CH_2^+ + H_2$	f(σ, EEDF)	6,7
$e + C_2H_2 \rightarrow 2e + C_2H_2^+$	f(σ, EEDF)	6,7
$e + C_2H_3 \rightarrow 2e + C_2H_3^+$	f(σ, EEDF)	6,7
$e + C_2H_3 \rightarrow 2e + C_2H_2^+ + H$	f(σ, EEDF)	6,7
$e + C_2H_4 \rightarrow 2e + C_2H_4^+$	f(σ, EEDF)	6,7
$e + C_2H_4 \rightarrow 2e + C_2H_3^+ + H$	f(σ, EEDF)	6,7
$e + C_2H_4 \rightarrow 2e + C_2H_2^+ + H_2$	f(σ, EEDF)	6,7
$e + C_2H_5 \rightarrow 2e + C_2H_5^+$	f(σ, EEDF)	6,7
$e + C_2H_5 \rightarrow 2e + C_2H_4^+ + H$	f(σ, EEDF)	6,7
$e + C_2H_5 \rightarrow 2e + C_2H_3^+ + H_2$	f(σ, EEDF)	6,7
$e + C_2H_5 \rightarrow 2e + C_2H_2^+ + H_2 + H$	f(σ, EEDF)	6,7
$e + C_2H_6 \rightarrow 2e + C_2H_6^+$	f(σ, EEDF)	6,7
$e + C_2H_6 \rightarrow 2e + C_2H_5^+ + H$	f(σ, EEDF)	6,7
$e + C_2H_6 \rightarrow 2e + C_2H_4^+ + H_2$	f(σ, EEDF)	6,7
$e + C_2H_6 \rightarrow 2e + C_2H_3^+ + H_2 + H$	f(σ, EEDF)	6,7
$e + C_2H_6 \rightarrow 2e + C_2H_2^+ + H_2 + H_2$	f(σ, EEDF)	6,7
$e + C_2H_6 \rightarrow 2e + CH_3^+ + CH_3$	f(σ, EEDF)	6,7
$e + C_3H_5 \rightarrow 2e + C_2H_3^+ + CH_2$	f(σ, EEDF)	6,7
$e + C_3H_5 \rightarrow 2e + C_2H_2^+ + CH_3$	f(σ, EEDF)	6,7
$e + C_3H_5 \rightarrow 2e + CH_3^+ + C_2H_2$	f(σ, EEDF)	6,7
$e + C_3H_6 \rightarrow 2e + C_2H_5^+ + CH$	f(σ, EEDF)	6,7
$e + C_3H_6 \rightarrow 2e + C_2H_4^+ + CH_2$	f(σ, EEDF)	6,7
$e + C_3H_6 \rightarrow 2e + C_2H_3^+ + CH_3$	f(σ, EEDF)	6,7
$e + C_3H_6 \rightarrow 2e + C_2H_2^+ + CH_4$	f(σ, EEDF)	6,7
$e + C_3H_6 \rightarrow 2e + CH_3^+ + C_2H_3$	f(σ, EEDF)	6,7
$e + C_3H_7 \rightarrow 2e + C_2H_5^+ + CH_2$	f(σ, EEDF)	6,7
$e + C_3H_7 \rightarrow 2e + C_2H_4^+ + CH_3$	f(σ, EEDF)	6,7
$e + C_3H_7 \rightarrow 2e + C_2H_3^+ + CH_4$	f(σ, EEDF)	6,7
$e + C_3H_7 \rightarrow 2e + CH_3^+ + C_2H_4$	f(σ, EEDF)	6,7

$e + C_3H_8 \rightarrow 2e + C_2H_5^+ + CH_3$	f(σ, EEDF)	6,7
$e + C_3H_8 \rightarrow 2e + C_2H_4^+ + CH_4$	f(σ, EEDF)	6,7

Table S6. Electron impact excited species attachment or ionization

Reaction	Rate coefficients	Ref
$e + O_2(e1) + CH_4 \rightarrow O_2^- + CH_4$	3.00×10^{-30}	6,7
$e + O_2(e2) + CH_4 \rightarrow O_2^- + CH_4$	3.00×10^{-30}	6,7
$e + O_2(e1) + H_2 \rightarrow O_2^- + H_2$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + H_2 \rightarrow O_2^- + H_2$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + CO_2 \rightarrow O_2^- + CO_2$	3.00×10^{-30}	6,7
$e + O_2(e2) + CO_2 \rightarrow O_2^- + CO_2$	3.00×10^{-30}	6,7
$e + O_2(e1) + CO \rightarrow O_2^- + CO$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + CO \rightarrow O_2^- + CO$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + CO(e1) \rightarrow O_2^- + CO(e1)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + CO(e1) \rightarrow O_2^- + CO(e1)$	$3.00\times1^{0-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + CO(e2) \rightarrow O_2^- + CO(e2)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + CO(e2) \rightarrow O_2^- + CO(e2)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + CO(e3) \rightarrow O_2^- + CO(e3)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + CO(e3) \rightarrow O_2^- + CO(e3)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + CO(e4) \rightarrow O_2^- + CO(e4)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + CO(e4) \rightarrow O_2^- + CO(e4)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + O_2 \rightarrow O_2^- + O_2$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + O_2(e1) \rightarrow O_2^- + O_2(e1)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) + O_2(e2) \rightarrow O_2^- + O_2(e2)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + O_2 \rightarrow O_2^- + O_2$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + O_2(e1) \rightarrow O_2^- + O_2(e1)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e2) + O_2(e2) \rightarrow O_2^- + O_2(e2)$	$3.00\times10^{-30}\times(2.0/3.0)$	6,7
$e + O_2(e1) \rightarrow 2e + O_2^+$	f(σ, EEDF)	6,7
$e + O_2(e1) \rightarrow 2e + O^+ + O$	f(σ, EEDF)	6,7
$e + O_2(e2) \rightarrow 2e + O_2^+$	f(σ, EEDF)	6,7
$e + O_2(e2) \rightarrow 2e + O^+ + O$	f(σ, EEDF)	6,7
$e + O_2(e3) \rightarrow 2e + O_2^+$	f(σ, EEDF)	6,7
$e + O_2(e3) \rightarrow 2e + O^+ + O$	f(σ, EEDF)	6,7
$e + CO(e1) \rightarrow 2e + CO^+$	f(σ, EEDF)	6,7

e + CO(e1) → 2e + C^+ + O	f(σ, EEDF)	6,7
e + CO(e1) → 2e + O^+ + C	f(σ, EEDF)	6,7
e + CO(e2) → 2e + CO^+	f(σ, EEDF)	6,7
e + CO(e2) → 2e + C^+ + O	f(σ, EEDF)	6,7
e + CO(e2) → 2e + O^+ + C	f(σ, EEDF)	6,7
e + CO(e3) → 2e + CO^+	f(σ, EEDF)	6,7
e + CO(e3) → 2e + C^+ + O	f(σ, EEDF)	6,7
e + CO(e3) → 2e + O^+ + C	f(σ, EEDF)	6,7
e + CO(e4) → 2e + CO^+	f(σ, EEDF)	6,7
e + CO(e4) → 2e + C^+ + O	f(σ, EEDF)	6,7
e + CO(e4) → 2e + O^+ + C	f(σ, EEDF)	6,7

Table S7. Electron impact de-excitation reactions

Reaction	Rate coefficients	Ref
e + O_2(e1) → e + O_2	f(σ, EEDF)	6,7
e + O_2(e2) → e + O_2	f(σ, EEDF)	6,7
e + O_2(e3) → e + O_2	f(σ, EEDF)	6,7
e + CO(e1) → CO + e	f(σ, EEDF)	6,7
e + CO(e2) → CO + e	f(σ, EEDF)	6,7
e + CO(e3) → CO + e	f(σ, EEDF)	6,7
e + CO(e4) → CO + e	f(σ, EEDF)	6,7

Table S8. Reactions stimulated by excited species

Reaction	Rate coefficients	Ref
$O(^1D)$ + H → OH	$4.36\times10^{-32}\times(298/T_g)^{1.0}$	17
$O(^1D)$ + O → O + O	8.00×10^{-12}	17
$O(^1D)$ + O_2 → O + O_2	$6.40\times10^{-12}\times\exp(67.0/T_g)$	17
$O(^1D)$ + O_3 → O_2 + O + O	1.20×10^{-10}	17
$O(^1D)$ + O_3 → O_2 + O_2	1.20×10^{-10}	17
$O(^1D)$ + H_2 → OH + H	$1.38\times10^{-10}\times\exp(21.0/T_g)$	17
$O(^1D)$ + H_2 → H_2 + O	$2.37\times10^{-10}\times\exp(120.7/T_g)$	17
$O(^1D)$ + OH → H + O_2	$6.00\times10^{-11}\times T_g^{-0.186}\times\exp(-154.0/T_g)$	17
$O(^1D)$ + HO_2 → OH + O_2	$2.90\times10^{-11}\times\exp(200.0/T_g)$	17
$O(^1D)$ + H_2O → OH + OH	$1.69\times10^{-10}\times\exp(36.0/T_g)$	17

$O(^1D) + H_2O \rightarrow H_2 + O_2$	2.20×10^{-12}	17
$O(^1D) + H_2O \rightarrow H_2O + O$	1.20×10^{-11}	17
$O(^1D) + H_2O_2 \rightarrow H_2O + O_2$	5.20×10^{-10}	17
$O(^1D) + H_2O_2 \rightarrow HO_2 + OH$	5.20×10^{-10}	17
$O(^1D) + CO \rightarrow O + CO$	$4.70\times10^{-11}\times\exp(-62.4/T_g)$	17
$O(^1D) + CO \rightarrow CO_2$	5.00×10^{-11}	23
$O(^1D) + CO_2 \rightarrow CO + O_2$	2.01×10^{-10}	17
$O(^1D) + CO_2 \rightarrow O + CO_2$	7.40×10^{-11}	17
$O(^1D) + CH_4 \rightarrow CH_4 + O$	$1.79\times10^{-13}\times\exp(107.0/T_g)$	17
$O(^1D) + CH_4 \rightarrow CH_3 + OH$	1.13×10^{-10}	17
$O(^1D) + CH_4 \rightarrow CH_2O + H_2$	7.50×10^{-12}	17
$O(^1D) + CH_4 \rightarrow CH_2OH + H$	3.00×10^{-11}	17
$O(^1D) + CH_2O \rightarrow CO + H_2O$	1.66×10^{-10}	17
$O(^1D) + CH_3OH \rightarrow CH_2OH + OH$	2.99×10^{-10}	17
$O(^1D) + C_2H_2 \rightarrow C_2H + OH$	2.20×10^{-10}	17
$O(^1D) + C_2H_2 \rightarrow CH_2(S)^{[2]} + CO$	2.66×10^{-10}	18
$O(^1D) + C_2H_2 \rightarrow C_2HO + H$	1.00×10^{-10}	18
$O(^1D) + C_2H_4 \rightarrow C_2H_3 + OH$	2.20×10^{-10}	17
$O(^1D) + C_2H_4 \rightarrow CH_2O + CH_2$	2.20×10^{-10}	17
$O(^1D) + C_2H_4 \rightarrow CHO + CH_3$	1.19×10^{-10}	17
$O(^1D) + C_2H_6 \rightarrow C_2H_6 + O$	7.31×10^{-10}	17
$O(^1D) + C_2H_6 \rightarrow C_2H_5 + OH$	6.29×10^{-10}	17
$O(^1D) + C_2H_6 \rightarrow CH_2OH + CH_3$	3.49×10^{-10}	18
$O(^1D) + C_2H_6 \rightarrow CH_3O + CH_3$	1.60×10^{-10}	17
$O(^1D) + C_2H_6 \rightarrow C_2H_5O + H$	1.60×10^{-10}	17
$O(^1D) + C_2H_6 \rightarrow CH_3CHOH + H$	1.60×10^{-10}	17
$O(^1D) + C_2H_6 \rightarrow CH_3CHO + H_2$	9.96×10^{-12}	18
$O(^1D) + C_3H_8 \rightarrow C_3H_8 + O$	9.51×10^{-10}	17
$O(^1D) + C_3H_8 \rightarrow C_3H_7 + OH$	2.20×10^{-10}	17
$O(^1S) \rightarrow O(^1D)$	1.34	19
$O(^1S) + H \rightarrow OH$	$4.36\times10^{-32}\times(298/T_g)^{1.0}$	17
$O(^1S) + O \rightarrow O(^1D) + O$	$5.00\times10^{-11}\times\exp(-301.0/T_g)$	17
$O(^1S) + O \rightarrow O + O$	$3.33\times10^{-11}\times\exp(-300.0/T_g)$	17
$O(^1S) + O_2 \rightarrow O + O_2$	$4.30\times10^{-12}\times\exp(-850.0/T_g)$	20

$O(^1S) + O_2 \rightarrow O(^1D) + O_2$	$1.30\times10^{-12}\times\exp(-850.0/T_g)$	21,23
$O(^1S) + O_2 \rightarrow O + O + O$	$3.00\times10^{-12}\times\exp(-850.0/T_g)$	17
$O(^1S) + O_3 \rightarrow O_2 + O_2$	2.90×10^{-10}	17
$O(^1S) + O_3 \rightarrow O(^1D) + O_2 + O$	2.90×10^{-10}	17
$O(^1S) + H_2 \rightarrow H_2 + O$	1.00×10^{-10}	17
$O(^1S) + H_2 \rightarrow OH + H$	2.60×10^{-16}	17
$O(^1S) + OH \rightarrow H + O_2$	$6.00\times10^{-11}\times T_g^{-0.186}\times\exp(-154.0/T_g)$	17
$O(^1S) + HO_2 \rightarrow OH + O_2$	$2.90\times10^{-11}\times\exp(200.0/T_g)$	17
$O(^1S) + H_2O \rightarrow H_2O + O(^1D)$	1.50×10^{-10}	17
$O(^1S) + H_2O \rightarrow H_2O + O$	4.50×10^{-11}	17
$O(^1S) + H_2O \rightarrow OH + OH$	3.00×10^{-10}	17
$O(^1S) + CO_2 \rightarrow CO + O_2$	2.00×10^{-10}	17
$O(^1S) + CO_2 \rightarrow CO_2 + O$	2.00×10^{-10}	17
$O(^1S) + CH_4 \rightarrow CH_3 + OH$	2.20×10^{-10}	17
$O(^1S) + CH_4 \rightarrow CH_2O + H_2$	2.40×10^{-11}	17
$O(^1S) + C_2H_2 \rightarrow C_2H + OH$	2.20×10^{-10}	17
$O(^1S) + C_2H_4 \rightarrow C_2H_3 + OH$	2.20×10^{-10}	17
$O(^1S) + C_2H_6 \rightarrow C_2H_5 + OH$	1.60×10^{-10}	17
$O(^1S) + C_2H_6 \rightarrow CH_3 + CH_3O$	1.60×10^{-10}	17
$O(^1S) + C_3H_8 \rightarrow C_3H_7 + OH$	2.20×10^{-10}	17
$O_2(e1) \rightarrow O_2$	2.60×10^{-4}	6,7
$O_2(e2) \rightarrow O_2$	1.10×10	6,7
$O_2(e1) + M \rightarrow O_2 + M$	$3.80\times10^{-18}\times\exp(-205.0/T_g)$	6,7
$O_2(e2) + M \rightarrow O_2 + M$	3.00×10^{-13}	6,7
$O_2(e1) + H_2 \rightarrow HO_2 + H$	$2.41\times10^{-10}\times\exp(-237.0\times10^3/(R\times T_g))$	6,7
$O_2(e2) + H_2 \rightarrow HO_2 + H$	$2.41\times10^{-10}\times\exp(-237.0\times10^3/(R\times T_g))$	6,7
$O_2(e1) + O \rightarrow O_2 + O$	7.00×10^{-16}	6,7
$O_2(e2) + O \rightarrow O_2(e1) + O$	$1.00\times10^{-11}\times\exp(-2300/T_g)$	6,7
$O_2(e1) + O + M \rightarrow O_3 + M$	$5.51\times10^{-34}\times(T_g/298)^{-2.6}$	6,7
$O_2(e2) + O + M \rightarrow O_3 + M$	$5.51\times10^{-34}\times(T_g/298)^{-2.6}$	6,7
$O_2(e1) + O_2 \rightarrow O_2 + O_2$	$3.80\times10^{-18}\times\exp(-205.0\times100/T_g)$	6,7
$O_2(e2) + O_2 \rightarrow O_2(e1) + O_2$	$4.30\times10^{-22}\times T_g^{2.4}\times\exp(-281/T_g)$	6,7
$O_2(e1) + O_3 \rightarrow O + O_2 + O_2(e1)$	2.29×10^{-26}	6,7
$O_2(e2) + O_3 \rightarrow O + O_2 + O_2(e2)$	2.29×10^{-26}	6,7

O_2(e1) + OH → HO_2 + O	$3.70\times10^{-11}\times\exp(-220000.0/(R\times T_g))$	6,7
O_2(e2) + OH → HO_2 + O	$3.70\times10^{-11}\times\exp(-220000.0/(R\times T_g))$	6,7
H_2O + O_2(e1) → HO_2 + OH	$7.72\times10^{-12}\times\exp(-310000.0/(R\times T_g))$	6,7
H_2O + O_2(e2) → HO_2 + OH	$7.72\times10^{-12}\times\exp(-310000.0/(R\times T_g))$	6,7
H_2O_2 + O_2(e1) → HO_2 + HO_2	$9.00\times10^{-11}\times\exp(-166000.0/(R\times T_g))$	6,7
H_2O_2 + O_2(e2) → HO_2 + HO_2	$9.00\times10^{-11}\times\exp(-166000.0/(R\times T_g))$	6,7
O_2(e1) + C → CO + O	3.00×10^{-11}	6,7
O_2(e2) + C → CO + O	3.00×10^{-11}	6,7
O_2(e1) + CH_3 → CH_3O + O	$1.25\times10^{-11}\times\exp(-118000.0/(R\times T_g))$	6,7
O_2(e2) + CH_3 → CH_3O + O	$1.25\times10^{-11}\times\exp(-118000.0/(R\times T_g))$	6,7
O_2(e1) + CH_4 → CH_3 + HO_2	$6.59\times10^{-11}\times\exp(-238000.0/(R\times T_g))$	6,7
O_2(e2) + CH_4 → CH_3 + HO_2	$6.59\times10^{-11}\times\exp(-238000.0/(R\times T_g))$	6,7
O_2(e1) + C_2H_2 → C_2H + HO_2	$2.01\times10^{-11}\times\exp(-312000.0/(R\times T_g))$	6,7
O_2(e2) + C_2H_2 → C_2H + HO_2	$2.01\times10^{-11}\times\exp(-312000.0/(R\times T_g))$	6,7
O_2(e1) + C_2H_3 → C_2H_2 + HO_2	$2.14\times10^{-14}\times(T_g/298)^{1.61}\times\exp(1.60\times10^{3}/(R\times T_g))$	6,7
O_2(e2) + C_2H_3 → C_2H_2 + HO_2	$2.14\times10^{-14}\times(T_g/298)^{1.61}\times\exp(1.60\times10^{3}/(R\times T_g))$	6,7
O_2(e1) + C_2H_5 → C_2H_5O + O	$6.14\times10^{-12}\times(T_g/298)^{-0.20}\times\exp(-1.17\times10^{5}/(R\times T_g))$	6,7
O_2(e2) + C_2H_5 → C_2H_5O + O	$6.14\times10^{-12}\times(T_g/298)^{-0.20}\times\exp(-1.17\times10^{5}/(R\times T_g))$	6,7
O_2(e1) + C_2H_6 → C_2H_5 + HO_2	$1.00\times10^{-10}\times\exp(-217000.0/(R\times T_g))$	6,7
O_2(e2) + C_2H_6 → C_2H_5 + HO_2	$1.00\times10^{-10}\times\exp(-217000.0/(R\times T_g))$	6,7
O_2(e1) + C_3H_6 → C_3H_5 + HO_2	$9.00\times10^{-11}\times\exp(-166000.0/(R\times T_g))$	6,7
O_2(e2) + C_3H_6 → C_3H_5 + HO_2	$9.00\times10^{-11}\times\exp(-166000.0/(R\times T_g))$	6,7
O_2(e1) + CO → CO_2 + O	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
O_2(e2) + CO → CO_2 + O	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
O_2(e1) + C_2O → CO_2 + CO	3.30×10^{-13}	6,7
O_2(e2) + C_2O → CO_2 + CO	3.30×10^{-13}	6,7
O_2(e1) + CH_3CHOH → CH_3CHO + HO_2	1.90×10^{-11}	6,7
O_2(e2) + CH_3CHOH → CH_3CHO + HO_2	1.90×10^{-11}	6,7
CO(e1) + M → CO + M	1.20×10^{-11}	6,7
CO(e2) + M → CO + M	1.20×10^{-11}	6,7
CO(e3) + M → CO + M	1.20×10^{-11}	6,7
CO(e4) + M → CO + M	1.20×10^{-11}	6,7
CO(e1) + O + M → CO_2 + M	$8.20\times10^{-34}\times\exp(-1510.0/T_g)\times2.000$	6,7
CO(e2) + O + M → CO_2 + M	$8.20\times10^{-34}\times\exp(-1510.0/T_g)\times2.000$	6,7

CO(e3) + O + M → CO_2 + M	$8.20\times10^{-34}\times\exp(-1510.0/T_g)\times2.000$	6,7
CO(e4) + O + M → CO_2 + M	$8.20\times10^{-34}\times\exp(-1510.0/T_g)\times2.000$	6,7
CO(e1) + O_2 → CO_2 + O	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
CO(e2) + O_2 → CO_2 + O	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
CO(e3) + O_2 → CO_2 + O	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
CO(e4) + O_2 → CO_2 + O	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
CO(e1) + O_3 → CO_2 + O_2	4.00×10^{-25}	6,7
CO(e2) + O_3 → CO_2 + O_2	4.00×10^{-25}	6,7
CO(e3) + O_3 → CO_2 + O_2	4.00×10^{-25}	6,7
CO(e4) + O_3 → CO_2 + O_2	4.00×10^{-25}	6,7
CO(e1) + OH → CO_2 + H	$5.40\times10^{-14}\times(T_g/298)^{1.50}\times\exp(2080/(R\times T_g))$	6,7
CO(e2) + OH → CO_2 + H	$5.40\times10^{-14}\times(T_g/298)^{1.50}\times\exp(2080/(R\times T_g))$	6,7
CO(e3) + OH → CO_2 + H	$5.40\times10^{-14}\times(T_g/298)^{1.50}\times\exp(2080/(R\times T_g))$	6,7
CO(e4) + OH → CO_2 + H	$5.40\times10^{-14}\times(T_g/298)^{1.50}\times\exp(2080/(R\times T_g))$	6,7
CO(e1) + HO_2 → CO_2 + OH	$2.51\times10^{-10}\times\exp(-98940/(R\times T_g))$	6,7
CO(e2) + HO_2 → CO_2 + OH	$2.51\times10^{-10}\times\exp(-98940/(R\times T_g))$	6,7
CO(e3) + HO_2 → CO_2 + OH	$2.51\times10^{-10}\times\exp(-98940/(R\times T_g))$	6,7
CO(e4) + HO_2 → CO_2 + OH	$2.51\times10^{-10}\times\exp(-98940/(R\times T_g))$	6,7
CO(e1) + C + M → C_2O + M	6.31×10^{-32}	6,7
CO(e2) + C + M → C_2O + M	6.31×10^{-32}	6,7
CO(e3) + C + M → C_2O + M	6.31×10^{-32}	6,7
CO(e4) + C + M → C_2O + M	6.31×10^{-32}	6,7
CO(e1) + CH_3 → C_2H_2 + OH	$6.31\times10^{-11}\times\exp(-253\times10^3/(R\times T_g))$	6,7
CO(e2) + CH_3 → C_2H_2 + OH	$6.31\times10^{-11}\times\exp(-253\times10^3/(R\times T_g))$	6,7
CO(e3) + CH_3 → C_2H_2 + OH	$6.31\times10^{-11}\times\exp(-253\times10^3/(R\times T_g))$	6,7
CO(e4) + CH_3 → C_2H_2 + OH	$6.31\times10^{-11}\times\exp(-253\times10^3/(R\times T_g))$	6,7
CO(e1) + CH_3O → CO_2 + CH_3	$2.61\times10^{-11}\times\exp(-49390/(R\times T_g))$	6,7
CO(e2) + CH_3O → CO_2 + CH_3	$2.61\times10^{-11}\times\exp(-49390/(R\times T_g))$	6,7
CO(e3) + CH_3O → CO_2 + CH_3	$2.61\times10^{-11}\times\exp(-49390/(R\times T_g))$	6,7
CO(e4) + CH_3O → CO_2 + CH_3	$2.61\times10^{-11}\times\exp(-49390/(R\times T_g))$	6,7
CO(e1) + C_2H_2 → C_2H + CHO	$8.00\times10^{-10}\times\exp(-446.0\times10^3/(R\times T_g))$	6,7
CO(e2) + C_2H_2 → C_2H + CHO	$8.00\times10^{-10}\times\exp(-446.0\times10^3/(R\times T_g))$	6,7
CO(e3) + C_2H_2 → C_2H + CHO	$8.00\times10^{-10}\times\exp(-446.0\times10^3/(R\times T_g))$	6,7
CO(e4) + C_2H_2 → C_2H + CHO	$8.00\times10^{-10}\times\exp(-446.0\times10^3/(R\times T_g))$	6,7

$CO(e1) + C_2H_4 \rightarrow CHO + C_2H_3$	$2.51\times10^{-10}\times\exp(-379000.0/(R\times T_g))$	6,7
$CO(e2) + C_2H_4 \rightarrow CHO + C_2H_3$	$2.51\times10^{-10}\times\exp(-379000.0/(R\times T_g))$	6,7
$CO(e3) + C_2H_4 \rightarrow CHO + C_2H_3$	$2.51\times10^{-10}\times\exp(-379000.0/(R\times T_g))$	6,7
$CO(e4) + C_2H_4 \rightarrow CHO + C_2H_3$	$2.51\times10^{-10}\times\exp(-379000.0/(R\times T_g))$	6,7
$O_2(e1) + CO(e1) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$O_2(e2) + CO(e1) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$O_2(e1) + CO(e2) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$O_2(e2) + CO(e2) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$O_2(e1) + CO(e3) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$O_2(e2) + CO(e3) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$O_2(e1) + CO(e4) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$O_2(e2) + CO(e4) \rightarrow CO_2 + O$	$4.20\times10^{-12}\times\exp(-24000.0/T_g)$	6,7
$C + OH \rightarrow CO(e1) + H$	$1.15\times10^{-10}\times(T_g/298)^{-0.34}$	6,7

[2]: $CH_2(S)$ is an isomer of CH_2.

Table S9. Ion-neutral reactions

Reaction	**Rate constants**	**Ref**
$C_2O_3^+ + CO \rightarrow C_2O_2^+ + CO_2$	1.10×10^{-9}	6,7
$H^+ + O_2 \rightarrow O_2^+ + H$	2.00×10^{-9}	24
$H_2^+ + O_2 \rightarrow O_2^+ + H_2$	8.00×10^{-10}	24
$O_2^+ + CHO \rightarrow CHO^+ + O_2$	$3.60\times10^{-10}\times(T_g/300)^{-0.50}$	24
$O_2^+ + CH \rightarrow CHO^+ + O$	$3.10\times10^{-10}\times(T_g/300)^{-0.50}$	24
$O_2^+ + CH_2O \rightarrow CHO^+ + O_2 + H$	$2.30\times10^{-10}\times(T_g/300)^{-0.50}$	24
$O_2^+ + C_2H_2 \rightarrow CHO^+ + H + CO$	6.50×10^{-11}	24
$O_2^+ + C_2H_4 \rightarrow C_2H_4^+ + O_2$	6.80×10^{-10}	24
$O_2^+ + C_2H_2 \rightarrow C_2H_2^+ + O_2$	1.11×10^{-9}	24
$CH_4^+ + O_2 \rightarrow O_2^+ + CH_4$	3.90×10^{-10}	24
$O_2^+ + CH_2 \rightarrow CH_2^+ + O_2$	4.30×10^{-10}	24
$O_2^+ + CH \rightarrow CH^+ + O_2$	3.10×10^{-10}	6,7
$H_2O^+ + O \rightarrow O_2^+ + H_2$	4.00×10^{-11}	24
$O^+ + OH \rightarrow O_2^+ + H$	$3.60\times10^{-10}\times(T_g/300)^{-0.50}$	24
$OH^+ + O \rightarrow O_2^+ + H$	7.10×10^{-10}	24
$O^+ + CO_2 \rightarrow O_2^+ + CO$	8.10×10^{-10}	6,7
$CO_2^+ + O_2 \rightarrow O_2^+ + CO_2$	5.30×10^{-11}	24

$CO_2^+ + O_2(e1) \rightarrow O_2^+ + CO_2$	$1.19\times5.30\times10^{-11}$	6,7
$CO_2^+ + O_2(e2) \rightarrow O_2^+ + CO_2$	$1.33\times5.30\times10^{-11}$	6,7
$CO_2^+ + O \rightarrow O_2^+ + CO$	1.64×10^{-10}	24
$CO^+ + O_2 \rightarrow O_2^+ + CO$	1.20×10^{-10}	24
$CO^+ + O_2(e1) \rightarrow O_2^+ + CO$	$1.19\times1.20\times10^{-10}$	6,7
$CO^+ + O_2(e2) \rightarrow O_2^+ + CO$	$1.33\times1.20\times10^{-10}$	6,7
$O_2^+ + C \rightarrow CO^+ + O$	5.20×10^{-11}	24
$O^+ + O_3 \rightarrow O_2^+ + O_2$	1.00×10^{-10}	6,7
$O_2^+ + C \rightarrow C^+ + O_2$	5.20×10^{-11}	24
$C_2O_2^+ + O_2 \rightarrow O_2^+ + CO + CO$	5.00×10^{-12}	6,7
$C_2O_2^+ + O_2(e1) \rightarrow O_2^+ + CO + CO$	5.00×10^{-12}	6,7
$C_2O_2^+ + O_2(e2) \rightarrow O_2^+ + CO + CO$	5.00×10^{-12}	6,7
$C_2O_2^+ + M \rightarrow CO^+ + CO + M$	1.00×10^{-12}	6,7
$C_2O_4^+ + CO \rightarrow C_2O_3^+ + CO_2$	9.00×10^{-10}	6,7
$C_2O_4^+ + CO(e1) \rightarrow C_2O_3^+ + CO_2$	9.00×10^{-10}	6,7
$C_2O_4^+ + CO(e2) \rightarrow C_2O_3^+ + CO_2$	9.00×10^{-10}	6,7
$C_2O_4^+ + CO(e3) \rightarrow C_2O_3^+ + CO_2$	9.00×10^{-10}	6,7
$C_2O_4^+ + CO(e4) \rightarrow C_2O_3^+ + CO_2$	9.00×10^{-10}	6,7
$C_2O_3^+ + CO(e1) \rightarrow C_2O_2^+ + CO_2$	1.10×10^{-9}	6,7
$C_2O_3^+ + CO(e2) \rightarrow C_2O_2^+ + CO_2$	1.10×10^{-9}	6,7
$C_2O_3^+ + CO(e3) \rightarrow C_2O_2^+ + CO_2$	1.10×10^{-9}	6,7
$C_2O_3^+ + CO(e4) \rightarrow C_2O_2^+ + CO_2$	1.10×10^{-9}	6,7
$CO_2^+ + CO_2 + M \rightarrow C_2O_4^+ + M$	3.00×10^{-28}	6,7
$C_2O_4^+ + M \rightarrow CO_2^+ + CO_2 + M$	1.00×10^{-14}	6,7
$O_4^+ + O \rightarrow O_2^+ + O_3$	3.00×10^{-10}	6,7
$O_4^+ + M \rightarrow O_2^+ + O_2 + M$	$3.30\times10^{-6}\times(300/T_g)^{4.0}\times\exp(-5030.0/T_g)$	6,7
$O_2^+ + O_2 + M \rightarrow O_4^+ + M$	$2.40\times10^{-30}\times(T_g/300)^{-3.2}$	6,7
$O_2^+ + O_2(e1) + M \rightarrow O_4^+ + M$	$2.40\times10^{-30}\times(T_g/300)^{-3.2}$	6,7
$O_2^+ + O_2(e2) + M \rightarrow O_4^+ + M$	$2.40\times10^{-30}\times(T_g/300)^{-3.2}$	6,7
$O_2^+ + C_2 \rightarrow C_2^+ + O_2$	4.10×10^{-10}	24
$O^+ + O_2 \rightarrow O_2^+ + O$	$1.90\times10^{-11}\times(T_g/300)^{-0.50}$	6,7
$O^+ + O_2(e1) \rightarrow O_2^+ + O$	$1.19\times1.90\times10^{-11}\times(T_g/300)^{-0.5}$	6,7
$O^+ + O_2(e2) \rightarrow O_2^+ + O$	$1.33\times1.90\times10^{-11}\times(T_g/300)^{-0.5}$	6,7
$O^+ + O + M \rightarrow O_2^+ + M$	1.00×10^{-29}	6,7

$H_2O^+ + O_2 \rightarrow O_2^+ + H_2O$	4.60×10^{-10}	24
$OH^+ + O_2 \rightarrow O_2^+ + OH$	5.90×10^{-10}	24
$O^+ + CHO \rightarrow CHO^+ + O$	$4.30\times10^{-10}\times(T_g/300)^{-0.50}$	24
$O^+ + CH_2O \rightarrow CHO^+ + OH$	$1.40\times10^{-9}\times(T_g/300)^{-0.50}$	24
$O^+ + C_2H_4 \rightarrow C_2H_4^+ + O$	7.00×10^{-11}	24
$O^+ + C_2H_4 \rightarrow C_2H_3^+ + OH$	2.10×10^{-10}	24
$O^+ + C_2H_4 \rightarrow C_2H_2^+ + H2O$	1.12×10^{-9}	24
$O^+ + C_2H_2 \rightarrow C_2H_2^+ + O$	3.90×10^{-11}	24
$O^+ + C_2H \rightarrow C_2H^+ + O$	4.60×10^{-10}	24
$O^+ + C_2H \rightarrow CO^+ + CH$	4.60×10^{-10}	24
$O^+ + CH_4 \rightarrow CH_4^+ + O$	8.90×10^{-10}	24
$O^+ + CH_4 \rightarrow CH_3^+ + OH$	1.10×10^{-10}	24
$O^+ + CH_2 \rightarrow CH_2^+ + O$	9.70×10^{-10}	24
$O^+ + CH \rightarrow CH^+ + O$	3.50×10^{-10}	6,7
$O^+ + C_2 \rightarrow C_2^+ + O$	4.80×10^{-10}	24
$O^+ + OH \rightarrow OH^+ + O$	3.60×10^{-10}	6,7
$O^+ + H_2O \rightarrow H_2O^+ + O$	3.20×10^{-9}	6,7
$O^+ + H_2 \rightarrow OH^+ + H$	1.70×10^{-9}	24
$CH^+ + O_2 \rightarrow O^+ + CHO$	1.00×10^{-11}	24
$O^+ + H \rightarrow H^+ + O$	5.82×10^{-10}	6,7
$H^+ + O \rightarrow O^+ + H$	3.44×10^{-10}	6,7
$O^+ + CO_2 \rightarrow CO_2^+ + O$	9.00×10^{-11}	6,7
$CO_2^+ + O \rightarrow O^+ + CO_2$	9.62×10^{-11}	24
$O^+ + CO \rightarrow CO^+ + O$	$4.90\times10^{-12}\times(T_g/300)^{0.5}\times\exp(-4580.0/T_g)$	24
$C^+ + O_2 \rightarrow O^+ + CO$	4.54×10^{-10}	24
$C^+ + O_2(e1) \rightarrow O^+ + CO$	4.54×10^{-10}	6,7
$C^+ + O_2(e2) \rightarrow O^+ + CO$	4.54×10^{-10}	6,7
$CO^+ + O \rightarrow O^+ + CO$	1.40×10^{-10}	24
$O^+ + CO(e1) \rightarrow CO^+ + O$	$1.58\times10^{-11}\times(T_g/300)^{0.5}\times\exp(-4580.0/T_g)$	6,7
$O^+ + CO(e2) \rightarrow CO^+ + O$	$2.59\times10^{-11}\times(T_g/300)^{0.5}\times\exp(-4580.0/T_g)$	6,7
$O^+ + CO(e3) \rightarrow CO^+ + O$	$1.23\times10^{-10}\times(T_g/300)^{0.5}\times\exp(-4580.0/T_g)$	6,7
$O^+ + CO(e4) \rightarrow CO^+ + O$	$7.81\times10^{-10}\times(T_g/300)^{0.5}\times\exp(-4580.0/T_g)$	6,7
$O^+ + C_2 \rightarrow CO^+ + C$	4.80×10^{-10}	24
$C^+ + C_3H_6 \rightarrow C_2H_2^+ + C_2H_4$	3.00×10^{-10}	24

$C^+ + C_3H_6 \rightarrow C_2H_3^+ + C_2H_3$	6.00×10^{-10}	24
$C^+ + CH_3OH \rightarrow CH_3^+ + CHO$	$2.08\times10^{-9}\times(T_g/300)^{-0.50}$	24
$C^+ + CHO \rightarrow CHO^+ + C$	$4.80\times10^{-10}\times(T_g/300)^{-0.50}$	24
$C^+ + CH_2O \rightarrow CHO^+ + CH$	$7.80\times10^{-10}\times(T_g/300)^{-0.50}$	24
$C^+ + H_2O \rightarrow CHO^+ + H$	$9.00\times10^{-10}\times(T_g/300)^{-0.50}$	24
$C^+ + CO_2 \rightarrow CO^+ + CO$	1.10×10^{-9}	24
$C^+ + CO \rightarrow CO^+ + C$	5.00×10^{-13}	6,7
$CO^+ + C \rightarrow C^+ + CO$	1.10×10^{-10}	24
$C^+ + CO(e1) \rightarrow CO^+ + C$	$3.23\times5.00\times10^{-13}$	6,7
$C^+ + CO(e2) \rightarrow CO^+ + C$	$5.28\times5.00\times10^{-13}$	6,7
$C^+ + CO(e3) \rightarrow CO^+ + C$	$23.18\times5.00\times10^{-13}$	6,7
$C^+ + CO(e4) \rightarrow CO^+ + C$	$159.31\times5.00\times10^{-13}$	6,7
$C^+ + O_2 \rightarrow CO^+ + O$	3.80×10^{-10}	6,7
$C^+ + O_2(e1) \rightarrow CO^+ + O$	3.80×10^{-10}	6,7
$C^+ + O_2(e2) \rightarrow CO^+ + O$	3.80×10^{-10}	6,7
$C^+ + C_2H_6 \rightarrow C_2H_5^+ + CH$	2.31×10^{-10}	24
$C^+ + C_2H_6 \rightarrow C_2H_4^+ + CH_2$	1.16×10^{-10}	24
$C^+ + C_2H_6 \rightarrow C_2H_3^+ + CH_3$	4.95×10^{-10}	24
$C^+ + C_2H_6 \rightarrow C_2H_2^+ + CH_4$	8.25×10^{-11}	24
$C^+ + CH \rightarrow CH^+ + C$	3.80×10^{-10}	6,7
$C^+ + CH \rightarrow C_2^+ + H$	3.80×10^{-10}	6,7
$C^+ + C_2H_5 \rightarrow C_2H_5^+ + C$	5.00×10^{-10}	24
$C^+ + C_2H_4 \rightarrow C_2H_4^+ + C$	1.70×10^{-11}	24
$C^+ + C_2H_4 \rightarrow C_2H_3^+ + CH$	8.50×10^{-11}	24
$C^+ + CH_4 \rightarrow C_2H_3^+ + H$	1.10×10^{-9}	24
$C^+ + CH_4 \rightarrow C_2H_2^+ + H_2$	4.00×10^{-10}	6,7
$C^+ + CH_3 \rightarrow C_2H_2^+ + H$	1.30×10^{-9}	24
$C^+ + CH_3 \rightarrow C_2H^+ + H_2$	1.00×10^{-9}	24
$C^+ + CH_2 \rightarrow C_2H^+ + H$	5.20×10^{-10}	24
$C^+ + CH_2 \rightarrow CH_2^+ + C$	5.20×10^{-10}	24
$C_2^+ + C \rightarrow C^+ + C_2$	1.10×10^{-10}	24
$CH^+ + H \rightarrow C^+ + H_2$	7.50×10^{-10}	6,7
$C_2^+ + CHO \rightarrow CHO^+ + C_2$	$3.80\times10^{-10}\times(T_g/300)^{-0.50}$	24
$C_2^+ + H_2O \rightarrow C_2H^+ + OH$	4.40×10^{-10}	24

$C_2^+ + O_2 \rightarrow CO^+ + CO$	8.00×10^{-10}	24
$O_2^+ + C_2 \rightarrow CO^+ + CO$	4.10×10^{-10}	6,7
$CO^+ + C_2 \rightarrow C_2^+ + CO$	8.40×10^{-10}	24
$C_2^+ + O \rightarrow CO^+ + C$	3.10×10^{-10}	24
$H_2O^+ + C_2 \rightarrow C_2^+ + H_2O$	4.70×10^{-10}	6,7
$C_2^+ + OH \rightarrow OH^+ + C_2$	6.50×10^{-10}	6,7
$OH^+ + C_2 \rightarrow C_2^+ + OH$	4.80×10^{-10}	24
$C_2^+ + CH_4 \rightarrow C_2H_2^+ + CH_2$	1.82×10^{-10}	24
$C_2^+ + CH_4 \rightarrow C_2H^+ + CH_3$	2.38×10^{-10}	24
$C_2^+ + H_2 \rightarrow C_2H^+ + H$	1.10×10^{-9}	24
$C_2^+ + CH_2 \rightarrow CH_2^+ + C_2$	4.50×10^{-10}	24
$C_2^+ + CH \rightarrow CH^+ + C_2$	3.20×10^{-10}	6,7
$CH^+ + CH \rightarrow C_2^+ + H_2$	7.40×10^{-10}	6,7
$H^+ + C_2H \rightarrow C_2^+ + H_2$	1.50×10^{-9}	24
$CH^+ + C \rightarrow C_2^+ + H$	1.20×10^{-9}	24
$H_2^+ + C_2 \rightarrow C_2^+ + H_2$	1.10×10^{-9}	24
$H^+ + C_2 \rightarrow C_2^+ + H$	3.10×10^{-9}	24
$H_2O^+ + CHO \rightarrow CHO^+ + H_2O$	$2.80\times10^{-10}\times(T_g/300)^{-0.50}$	24
$H_2O^+ + CO \rightarrow CHO^+ + OH$	5.00×10^{-10}	24
$H_2O^+ + CO(e1) \rightarrow CHO^+ + OH$	5.00×10^{-10}	6,7
$H_2O^+ + CO(e2) \rightarrow CHO^+ + OH$	5.00×10^{-10}	6,7
$H_2O^+ + CO(e3) \rightarrow CHO^+ + OH$	5.00×10^{-10}	6,7
$H_2O+ + CO(e4) \rightarrow CHO^+ + OH$	5.00×10^{-10}	6,7
$CHO^+ + OH \rightarrow H_2O^+ + CO$	$6.20\times10^{-10}\times(T_g/300)^{-0.50}$	24
$H_2O^+ + C_2 \rightarrow C_2H^+ + OH$	4.70×10^{-10}	24
$CH_5^+ + OH \rightarrow H_2O^+ + CH_4$	7.00×10^{-10}	6,7
$H_3^+ + O \rightarrow H_2O^+ + H$	3.60×10^{-10}	6,7
$H_3^+ + OH \rightarrow H_2O^+ + H_2$	1.30×10^{-9}	6,7
$H_2^+ + OH \rightarrow H_2O^+ + H$	7.60×10^{-10}	6,7
$H_2^+ + H_2O \rightarrow H_2O^+ + H_2$	3.90×10^{-9}	6,7
$H^+ + H_2O \rightarrow H_2O^+ + H$	6.90×10^{-9}	6,7
$CO_2^+ + H_2O \rightarrow H_2O^+ + CO_2$	2.04×10^{-9}	6,7
$CO^+ + H_2O \rightarrow H_2O^+ + CO$	1.72×10^{-9}	6,7
$H_2O^+ + CH_4 \rightarrow H_3O^+ + CH_3$	1.40×10^{-9}	24

$H_2O^+ + CH_2 \rightarrow CH_3^+ + OH$	4.70×10^{-10}	24
$H_2O^+ + CH_2 \rightarrow CH_2^+ + H_2O$	4.70×10^{-10}	24
$H_2O^+ + CH \rightarrow CH_2^+ + OH$	3.40×10^{-10}	6,7
$H_2O^+ + CH \rightarrow CH^+ + H_2O$	3.40×10^{-10}	6,7
$H_2O^+ + C \rightarrow CH^+ + OH$	1.10×10^{-9}	24
$H_2O^+ + C_2H_6 \rightarrow H_3O^+ + C_2H_5$	1.33×10^{-9}	24
$H_2O^+ + C_2H_6 \rightarrow C_2H_6^+ + H_2O$	6.40×10^{-11}	24
$H_2O^+ + C_2H_6 \rightarrow C_2H_4^+ + H_2O + H_2$	1.92×10^{-10}	24
$H_2O^+ + C_2H_4 \rightarrow C_2H_4^+ + H_2O$	1.50×10^{-9}	24
$H_2O^+ + C_2H_2 \rightarrow C_2H_2^+ + H_2O$	1.90×10^{-9}	24
$H_2O^+ + C_2H \rightarrow C_2H_2^+ + OH$	4.40×10^{-10}	24
$H_2O^+ + C_2H \rightarrow C_2H^+ + H_2O$	4.40×10^{-10}	24
$H_2O^+ + H_2 \rightarrow H_3O^+ + H$	6.40×10^{-10}	24
$H_2O^+ + H_2O \rightarrow H_3O^+ + OH$	2.10×10^{-9}	6,7
$H_2O^+ + OH \rightarrow H_3O^+ + O$	6.90×10^{-10}	6,7
$OH^+ + H_2 \rightarrow H_2O^+ + H$	1.01×10^{-9}	24
$OH^+ + H_2O \rightarrow H_2O^+ + OH$	1.59×10^{-9}	6,7
$OH^+ + OH \rightarrow H_2O^+ + O$	7.00×10^{-10}	6,7
$OH^+ + CHO \rightarrow CHO^+ + OH$	$2.80\times10^{-10}\times(T_g/300)^{-0.50}$	24
$OH^+ + CO \rightarrow CHO^+ + O$	1.05×10^{-9}	24
$OH^+ + CO(e1) \rightarrow CHO^+ + O$	1.05×10^{-9}	6,7
$OH^+ + CO(e2) \rightarrow CHO^+ + O$	1.05×10^{-9}	6,7
$OH^+ + CO(e3) \rightarrow CHO^+ + O$	1.05×10^{-9}	6,7
$OH^+ + CO(e4) \rightarrow CHO^+ + O$	1.05×10^{-9}	6,7
$OH^+ + C_2 \rightarrow C_2H^+ + O$	4.80×10^{-10}	24
$H_3^+ + O \rightarrow OH^+ + H_2$	8.40×10^{-10}	6,7
$H_2^+ + O \rightarrow OH^+ + H$	1.50×10^{-9}	24
$H_2^+ + OH \rightarrow OH^+ + H_2$	7.60×10^{-10}	6,7
$H^+ + OH \rightarrow OH^+ + H$	2.10×10^{-9}	6,7
$CO^+ + OH \rightarrow OH^+ + CO$	3.10×10^{-10}	6,7
$OH^+ + CH_4 \rightarrow CH_5^+ + O$	1.95×10^{-10}	24
$OH^+ + CH_4 \rightarrow H_3O^+ + CH_2$	1.31×10^{-9}	24
$OH^+ + CH_2 \rightarrow CH_3^+ + O$	4.80×10^{-10}	24
$OH^+ + CH_2 \rightarrow CH_2^+ + OH$	4.80×10^{-10}	24

$OH^+ + CH \rightarrow CH_2^+ + O$	3.50×10^{-10}	6,7
$OH^+ + CH \rightarrow CH^+ + OH$	3.50×10^{-10}	6,7
$OH^+ + C \rightarrow CH^+ + O$	1.20×10^{-9}	24
$OH^+ + C_2H_6 \rightarrow H_3O^+ + C_2H_4$	1.60×10^{-10}	24
$OH^+ + C_2H_6 \rightarrow C_2H_6^+ + OH$	4.80×10^{-11}	24
$OH^+ + C_2H_6 \rightarrow C_2H_5^+ + H_2 + O$	3.20×10^{-10}	24
$OH^+ + C_2H_6 \rightarrow C_2H_4^+ + H_2 + OH$	1.04×10^{-9}	24
$OH^+ + C_2H \rightarrow C_2H_2^+ + O$	4.50×10^{-10}	24
$OH^+ + C_2H \rightarrow C_2H^+ + OH$	4.50×10^{-10}	24
$OH^+ + H_2O \rightarrow H_3O^+ + O$	1.30×10^{-9}	24
$H_3O^+ + C \rightarrow CHO^+ + H_2$	1.00×10^{-11}	24
$CHO^+ + H_2O \rightarrow H_3O^+ + CO$	$2.50\times10^{-9}\times(T_g/300)^{-0.50}$	24
$H_3O^+ + C_2 \rightarrow C_2H^+ + H_2O$	9.20×10^{-10}	24
$CH_5^+ + O \rightarrow H_3O^+ + CH_2$	2.20×10^{-10}	24
$CH_5^+ + H_2O \rightarrow H_3O^+ + CH_4$	3.70×10^{-9}	24
$CH_4^+ + H_2O \rightarrow H_3O^+ + CH_3$	2.60×10^{-9}	6,7
$CH^+ + H_2O \rightarrow H_3O^+ + C$	5.50×10^{-10}	6,7
$C_2H_6^+ + H_2O \rightarrow H_3O^+ + C_2H_5$	2.95×10^{-9}	24
$C_2H_5^+ + H_2O \rightarrow H_3O^+ + C_2H_4$	1.40×10^{-9}	6,7
$C_2H_3^+ + H_2O \rightarrow H_3O^+ + C_2H_2$	1.11×10^{-9}	6,7
$C_2H_2^+ + H_2O \rightarrow H_3O^+ + C_2H$	2.20×10^{-10}	6,7
$H_3^+ + H_2O \rightarrow H_3O^+ + H_2$	5.90×10^{-9}	6,7
$H_2^+ + H_2O \rightarrow H_3O^+ + H$	3.40×10^{-9}	6,7
$H_3O^+ + CH_2 \rightarrow CH_3^+ + H_2O$	9.40×10^{-10}	24
$H_3O^+ + CH \rightarrow CH_2^+ + H_2O$	6.80×10^{-10}	6,7
$H_3O^+ + C_2H_3 \rightarrow C_2H_4^+ + H_2O$	2.00×10^{-9}	6,7
$H_3^+ + C_2H_5OH \rightarrow C_2H_3^+ + H_2O + H_2 + H_2$	$4.00\times10^{-10}\times(T_g/300)^{-0.50}$	24
$H_3^+ + C_3H_6 \rightarrow C_2H_3^+ + CH_4 + H_2$	9.00×10^{-10}	24
$H_3^+ + CH_3CHO \rightarrow C_2H_3^+ + H_2 + H_2O$	$8.97\times10^{-10}\times(T_g/300)^{-0.50}$	24
$H_3^+ + C_2H_5OH \rightarrow CH_3^+ + CH_4 + H_2O$	$1.50\times10^{-9}\times(T_g/300)^{-0.50}$	24
$H_3^+ + CH_3CHO \rightarrow CH_3^+ + CH_3OH$	$1.45\times10^{-9}\times(T_g/300)^{-0.50}$	24
$H_3^+ + CH_3OH \rightarrow CH_3^+ + H_2O + H_2$	$3.71\times10^{-9}\times(T_g/300)^{-0.50}$	24
$H_3^+ + CO \rightarrow CHO^+ + H_2$	$1.36\times10^{-9}\times(T_g/300)^{-0.14}\times\exp(3.40/T_g)$	24
$H_3^+ + CO(e1) \rightarrow CHO^+ + H_2$	$1.36\times10^{-9}\times(T_g/300)^{-0.14}\times\exp(3.40/T_g)$	6,7

$H_3^+ + CO(e2) \rightarrow CHO^+ + H_2$	$1.36\times10^{-9}\times(T_g/300)^{-0.14}\times\exp(3.40/T_g)$	6,7
$H_3^+ + CO(e3) \rightarrow CHO^+ + H_2$	$1.36\times10^{-9}\times(T_g/300)^{-0.14}\times\exp(3.40/T_g)$	6,7
$H_3^+ + CO(e4) \rightarrow CHO^+ + H_2$	$1.36\times10^{-9}\times(T_g/300)^{-0.14}\times\exp(3.40/T_g)$	6,7
$H_3^+ + C_2 \rightarrow C_2H^+ + H_2$	1.80×10^{-9}	24
$H_2^+ + H_2 \rightarrow H_3^+ + H + H$	2.11×10^{-9}	6,7
$H^+ + H_2 + H_2 \rightarrow H_3^+ + H_2$	$3.10\times10^{-29}\times(300/T_g)^{0.5}$	6,7
$H_3^+ + CH_4 \rightarrow CH_5^+ + H_2$	2.40×10^{-9}	24
$H_3^+ + CH_3 \rightarrow CH_4^+ + H_2$	2.10×10^{-9}	24
$H_3^+ + CH_2 \rightarrow CH_3^+ + H_2$	1.70×10^{-9}	24
$H_3^+ + CH \rightarrow CH_2^+ + H_2$	1.20×10^{-9}	6,7
$H_3^+ + C \rightarrow CH^+ + H_2$	2.00×10^{-9}	24
$H_3^+ + C_2H_6 \rightarrow C_2H_5^+ + H_2 + H_2$	2.40×10^{-9}	24
$H_3^+ + C_2H_5 \rightarrow C_2H_6^+ + H_2$	1.40×10^{-9}	24
$H_3^+ + C_2H_4 \rightarrow C_2H_5^+ + H_2$	1.15×10^{-9}	24
$H_3^+ + C_2H_4 \rightarrow C_2H_3^+ + H_2 + H_2$	1.15×10^{-9}	24
$H_3^+ + C_2H_3 \rightarrow C_2H_4^+ + H_2$	2.00×10^{-9}	6,7
$H_3^+ + C_2H_2 \rightarrow C_2H_3^+ + H_2$	3.50×10^{-9}	24
$H_2^+ + H \rightarrow H_3^+$	2.10×10^{-9}	6,7
$H^+ + H_2 + M \rightarrow H_3^+ + M$	1.50×10^{-29}	6,7
$H_3^+ + C_2H \rightarrow C_2H_2^+ + H_2$	1.70×10^{-9}	24
$H_2^+ + CHO \rightarrow CHO^+ + H_2$	$1.00\times10^{-9}\times(T_g/300)^{-0.50}$	24
$H_2^+ + CO \rightarrow CHO^+ + H$	2.16×10^{-9}	24
$H_2^+ + CO(e1) \rightarrow CHO^+ + H$	2.16×10^{-9}	6,7
$H_2^+ + CO(e2) \rightarrow CHO^+ + H$	2.16×10^{-9}	6,7
$H_2^+ + CO(e3) \rightarrow CHO^+ + H$	2.16×10^{-9}	6,7
$H_2^+ + CO(e4) \rightarrow CHO^+ + H$	2.16×10^{-9}	6,7
$H_2^+ + CH_2O \rightarrow CHO^+ + H_2 + H$	$1.40\times10^{-9}\times(T_g/300)^{-0.50}$	24
$H_2^+ + C_2 \rightarrow C_2H^+ + H$	1.10×10^{-9}	24
$H_2^+ + CH_4 \rightarrow CH_5^+ + H$	1.14×10^{-10}	24
$H_2^+ + CH_4 \rightarrow CH_4^+ + H_2$	1.40×10^{-9}	24
$H_2^+ + CH_4 \rightarrow CH_3^+ + H_2 + H$	2.30×10^{-9}	24
$H_2^+ + CH_2 \rightarrow CH_3^+ + H$	1.00×10^{-9}	24
$H_2^+ + CH_2 \rightarrow CH_2^+ + H_2$	1.00×10^{-9}	24
$H_2^+ + CH \rightarrow CH_2^+ + H$	7.10×10^{-10}	6,7

$H_2^+ + CH \rightarrow CH^+ + H_2$	7.10×10^{-10}	6,7
$H_2^+ + C \rightarrow CH^+ + H$	2.40×10^{-9}	24
$H_2^+ + C_2H_6 \rightarrow C_2H_6^+ + H_2$	2.94×10^{-10}	24
$H_2^+ + C_2H_6 \rightarrow C_2H_5^+ + H_2 + H$	1.37×10^{-9}	24
$H_2^+ + C_2H_6 \rightarrow C_2H_4^+ + H_2 + H_2$	2.35×10^{-9}	24
$H_2^+ + C_2H_6 \rightarrow C_2H_3^+ + H_2 + H_2 + H$	6.86×10^{-10}	6,7
$H_2^+ + C_2H_6 \rightarrow C_2H_2^+ + H_2 + H_2 + H_2$	1.96×10^{-10}	6,7
$H_2^+ + C_2H_4 \rightarrow C_2H_4^+ + H_2$	2.21×10^{-9}	24
$H_2^+ + C_2H_4 \rightarrow C_2H_3^+ + H_2 + H$	1.81×10^{-9}	24
$H_2^+ + C_2H_4 \rightarrow C_2H_2^+ + H_2 + H_2$	8.82×10^{-10}	24
$H_2^+ + C_2H_2 \rightarrow C_2H_3^+ + H$	4.80×10^{-10}	24
$H_2^+ + C_2H_2 \rightarrow C_2H_2^+ + H_2$	4.82×10^{-9}	24
$H_2^+ + C_2H \rightarrow C_2H_2^+ + H$	1.00×10^{-9}	24
$H_2^+ + C_2H \rightarrow C_2H^+ + H_2$	1.00×10^{-9}	24
$H_2^+ + H_2 \rightarrow H^+ + H_2 + H$	$1.00\times10^{-8}\times\exp(-84100/T_g)$	6,7
$H_2^+ + H \rightarrow H^+ + H_2$	6.39×10^{-10}	24
$H^+ + H + M \rightarrow H_2^+ + M$	1.00×10^{-34}	6,7
$H^+ + CH_3OH \rightarrow CH_3^+ + H_2O$	$5.90\times10^{-10}\times(T_g/300)^{-0.50}$	24
$H^+ + CHO \rightarrow CHO^+ + H$	$9.40\times10^{-10}\times(T_g/300)^{-0.50}$	24
$H^+ + CH_3OH \rightarrow CHO^+ + H_2 + H_2$	$8.85\times10^{-10}\times(T_g/300)^{-0.50}$	24
$H^+ + CO_2 \rightarrow CHO^+ + O$	3.50×10^{-9}	24
$H^+ + CH_2O \rightarrow CHO^+ + H_2$	$3.57\times10^{-9}\times(T_g/300)^{-0.50}$	24
$H^+ + CH_4 \rightarrow CH_4^+ + H$	1.50×10^{-9}	24
$H^+ + CH_4 \rightarrow CH_3^+ + H_2$	2.30×10^{-9}	24
$H^+ + CH_3 \rightarrow CH_3^+ + H$	3.40×10^{-9}	24
$H^+ + CH_2 \rightarrow CH_2^+ + H$	1.40×10^{-9}	24
$H^+ + CH_2 \rightarrow CH^+ + H_2$	1.40×10^{-9}	24
$H^+ + CH \rightarrow CH^+ + H$	1.90×10^{-9}	6,7
$H^+ + C_2H_6 \rightarrow C_2H_5^+ + H_2$	1.30×10^{-9}	6,7
$H^+ + C_2H_6 \rightarrow C_2H_4^+ + H_2 + H$	1.40×10^{-9}	24
$H^+ + C_2H_6 \rightarrow C_2H_3^+ + H_2 + H_2$	2.80×10^{-9}	24
$H^+ + C_2H_5 \rightarrow C_2H_4^+ + H_2$	1.65×10^{-9}	24
$H^+ + C_2H_5 \rightarrow C_2H_3^+ + H_2 + H$	3.06×10^{-9}	24
$H^+ + C_2H_4 \rightarrow C_2H_4^+ + H$	1.00×10^{-9}	24

$H^+ + C_2H_4 \rightarrow C_2H_3^+ + H_2$	3.00×10^{-9}	24
$H^+ + C_2H_4 \rightarrow C_2H_2^+ + H_2 + H$	1.00×10^{-9}	24
$H^+ + C_2H_3 \rightarrow C_2H_3^+ + H$	2.00×10^{-9}	6,7
$H^+ + C_2H_3 \rightarrow C_2H_2^+ + H_2$	2.00×10^{-9}	6,7
$H^+ + C_2H_2 \rightarrow C_2H_2^+ + H$	5.40×10^{-10}	24
$H^+ + C_2H \rightarrow C_2H^+ + H$	1.50×10^{-9}	24
$CO^+ + CHO \rightarrow CHO^+ + CO$	$7.40\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CO^+ + C_2H \rightarrow CHO^+ + C_2$	3.90×10^{-10}	24
$CO^+ + CH_2 \rightarrow CHO^+ + CH$	4.30×10^{-10}	24
$CO^+ + CH_4 \rightarrow CHO^+ + CH_3$	4.55×10^{-10}	24
$CO^+ + CH \rightarrow CHO^+ + C$	$3.20\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CO^+ + CH_2O \rightarrow CHO^+ + CHO$	$1.65\times10^{-9}\times(T_g/300)^{-0.50}$	24
$CO^+ + H_2 \rightarrow CHO^+ + H$	7.50×10^{-10}	24
$CO^+ + H_2O \rightarrow CHO^+ + OH$	$8.84\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CO^+ + OH \rightarrow CHO^+ + O$	$3.10\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CO^+ + CO_2 \rightarrow CO_2^+ + CO$	1.00×10^{-9}	24
$CH^+ + O \rightarrow CO^+ + H$	3.50×10^{-10}	24
$CH^+ + O_2 \rightarrow CO^+ + OH$	1.00×10^{-11}	24
$H_2^+ + CO \rightarrow CO^+ + H_2$	6.44×10^{-10}	24
$CO^+ + CH_4 \rightarrow CH_4^+ + CO$	7.93×10^{-10}	24
$CO^+ + CH_2 \rightarrow CH_2^+ + CO$	4.30×10^{-10}	24
$CO^+ + CH \rightarrow CH^+ + CO$	3.20×10^{-10}	6,7
$CO^+ + C_2H \rightarrow C_2H^+ + CO$	3.90×10^{-10}	24
$CO^+ + H \rightarrow H^+ + CO$	7.50×10^{-10}	24
$CO_2^+ + H \rightarrow CHO^+ + O$	2.90×10^{-10}	24
$CO_2^+ + CH_4 \rightarrow CH_4^+ + CO_2$	5.50×10^{-10}	24
$CO_2^+ + C_2H_4 \rightarrow C_2H_4^+ + CO_2$	1.50×10^{-10}	24
$CO_2^+ + C_2H_2 \rightarrow C_2H_2^+ + CO_2$	7.30×10^{-10}	24
$CH^+ + CH_3OH \rightarrow CH_3^+ + CH_2O$	$1.45\times10^{-9}\times(T_g/300)^{-0.50}$	24
$CH^+ + CH_2O \rightarrow CH_3^+ + CO$	$9.60\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CH^+ + CHO \rightarrow CHO^+ + CH$	$4.60\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CH^+ + CO_2 \rightarrow CHO^+ + CO$	1.60×10^{-9}	24
$CH^+ + CH_2O \rightarrow CHO^+ + CH_2$	$9.60\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CH^+ + H_2O \rightarrow CHO^+ + H_2$	$2.90\times10^{-9}\times(T_g/300)^{-0.50}$	24

$CH^+ + O_2 \rightarrow CHO^+ + O$	9.70×10^{-10}	24
$CH^+ + O_2(e1) \rightarrow CHO^+ + O$	9.70×10^{-10}	6,7
$CH^+ + O_2(e2) \rightarrow CHO^+ + O$	9.70×10^{-10}	6,7
$CHO^+ + C \rightarrow CH^+ + CO$	1.10×10^{-9}	24
$CH_5^+ + C \rightarrow CH^+ + CH_4$	1.20×10^{-9}	24
$CH^+ + CH_4 \rightarrow C_2H_4^+ + H$	6.50×10^{-11}	24
$CH^+ + CH_4 \rightarrow C_2H_3^+ + H_2$	1.09×10^{-9}	24
$CH^+ + CH_4 \rightarrow C_2H_2^+ + H_2 + H$	1.43×10^{-10}	24
$CH^+ + CH_2 \rightarrow C_2H^+ + H_2$	1.00×10^{-9}	24
$CH^+ + H_2 \rightarrow CH_2^+ + H$	1.20×10^{-9}	24
$CH_2^+ + CHO \rightarrow CH_3^+ + CO$	$4.50\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CH_2^+ + CH_2O \rightarrow CHO^+ + CH_3$	$2.81\times10^{-9}\times(T_g/300)^{-0.50}$	24
$CH_2^+ + O_2 \rightarrow CHO^+ + OH$	9.10×10^{-10}	24
$CH_2^+ + O_2(e1) \rightarrow CHO^+ + OH$	9.10×10^{-10}	6,7
$CH_2^+ + O_2(e2) \rightarrow CHO^+ + OH$	9.10×10^{-10}	6,7
$CH_2^+ + O \rightarrow CHO^+ + H$	7.50×10^{-10}	24
$CHO^+ + CH \rightarrow CH_2^+ + CO$	$6.30\times10^{-10}\times(T_g/300)^{-0.50}$	24
$C_2H^+ + CH \rightarrow CH_2^+ + C_2$	3.20×10^{-10}	6,7
$CH_5^+ + CH \rightarrow CH_2^+ + CH_4$	6.90×10^{-10}	6,7
$CH_2^+ + CH_4 \rightarrow CH_3^+ + CH_3$	1.38×10^{-10}	6,7
$CH_2^+ + CH_4 \rightarrow C_2H_5^+ + H$	3.60×10^{-10}	24
$CH_2^+ + CH_4 \rightarrow C_2H_4^+ + H_2$	8.40×10^{-10}	24
$CH_2^+ + CH_4 \rightarrow C_2H_3^+ + H_2 + H$	2.31×10^{-10}	6,7
$CH_2^+ + CH_4 \rightarrow C_2H_2^+ + H_2 + H_2$	3.97×10^{-10}	6,7
$CH_2^+ + H_2 \rightarrow CH_3^+ + H$	1.60×10^{-9}	24
$CH_2^+ + C \rightarrow C_2H^+ + H$	1.20×10^{-9}	24
$CH_3^+ + CHO \rightarrow CHO^+ + CH_3$	$4.40\times10^{-10}\times(T_g/300)^{-0.50}$	24
$CH_3^+ + CH_2O \rightarrow CHO^+ + CH_4$	$1.60\times10^{-9}\times(T_g/300)^{-0.50}$	24
$CH_3^+ + O \rightarrow CHO^+ + H_2$	4.00×10^{-10}	24
$CHO^+ + CH_2 \rightarrow CH_3^+ + CO$	8.60×10^{-10}	24
$C_2H^+ + CH_2 \rightarrow CH_3^+ + C_2$	4.40×10^{-10}	24
$CH_5^+ + CH_2 \rightarrow CH_3^+ + CH_4$	9.60×10^{-10}	24
$CH_4^+ + H \rightarrow CH_3^+ + H_2$	1.00×10^{-11}	24
$CH_3^+ + CH_4 \rightarrow CH_4^+ + CH_3$	1.36×10^{-10}	6,7

$CH_3^+ + CH_4 \rightarrow C_2H_5^+ + H_2$	1.20×10^{-9}	24
$CH_3^+ + CH_2 \rightarrow C_2H_3^+ + H_2$	9.90×10^{-10}	24
$CH_3^+ + CH \rightarrow C_2H_2^+ + H_2$	7.10×10^{-10}	6,7
$CH_3^+ + C \rightarrow C_2H^+ + H_2$	1.20×10^{-9}	24
$CH_3^+ + C_2H_6 \rightarrow C_2H_5^+ + CH_4$	1.48×10^{-9}	24
$CH_3^+ + C_2H_4 \rightarrow C_2H_3^+ + CH_4$	3.50×10^{-10}	24
$CH_3^+ + C_2H_3 \rightarrow C_2H_3^+ + CH_3$	3.00×10^{-10}	6,7
$CH_4^+ + O \rightarrow CH_3^+ + OH$	1.00×10^{-9}	24
$C_2H_4^+ + O \rightarrow CH_3^+ + CHO$	1.08×10^{-10}	24
$CH_4^+ + CO \rightarrow CHO^+ + CH_3$	1.40×10^{-9}	24
$CH_4^+ + CO(e1) \rightarrow CHO^+ + CH_3$	1.40×10^{-9}	6,7
$CH_4^+ + CO(e2) \rightarrow CHO^+ + CH_3$	1.40×10^{-9}	6,7
$CH_4^+ + CO(e3) \rightarrow CHO^+ + CH_3$	1.40×10^{-9}	6,7
$CH_4^+ + CO(e4) \rightarrow CHO^+ + CH_3$	1.40×10^{-9}	6,7
$CH_5^+ + H \rightarrow CH_4^+ + H_2$	1.50×10^{-10}	24
$CH_4^+ + CH_4 \rightarrow CH_5^+ + CH_3$	1.50×10^{-9}	24
$CH_4^+ + C_2H_6 \rightarrow C_2H_4^+ + CH_4 + H_2$	1.91×10^{-9}	6,7
$CH_4^+ + C_2H_4 \rightarrow C_2H_5^+ + CH_3$	4.23×10^{-10}	24
$CH_4^+ + C_2H_4 \rightarrow C_2H_4^+ + CH_4$	1.38×10^{-9}	24
$CH_4^+ + C_2H_2 \rightarrow C_2H_3^+ + CH_3$	1.23×10^{-9}	24
$CH_4^+ + C_2H_2 \rightarrow C_2H_2^+ + CH_4$	1.13×10^{-9}	24
$CH_4^+ + H_2 \rightarrow CH_5^+ + H$	3.30×10^{-11}	6,7
$CH_5^+ + CO \rightarrow CHO^+ + CH_4$	1.00×10^{-9}	24
$CH_5^+ + CO(e1) \rightarrow CHO^+ + CH_4$	1.00×10^{-9}	6,7
$CH_5^+ + CO(e2) \rightarrow CHO^+ + CH_4$	1.00×10^{-9}	6,7
$CH_5^+ + CO(e3) \rightarrow CHO^+ + CH_4$	1.00×10^{-9}	6,7
$CH_5^+ + CO(e4) \rightarrow CHO^+ + CH_4$	1.00×10^{-9}	6,7
$CH_5^+ + C_2 \rightarrow C_2H^+ + CH_4$	9.50×10^{-10}	24
$CH_5^+ + C_2H_6 \rightarrow C_2H_5^+ + H_2 + CH_4$	2.25×10^{-10}	6,7
$CH_5^+ + C_2H_4 \rightarrow C_2H_5^+ + CH_4$	1.50×10^{-9}	24
$CH_5^+ + C_2H_2 \rightarrow C_2H_3^+ + CH_4$	1.60×10^{-9}	24
$CH_5^+ + C_2H \rightarrow C_2H_2^+ + CH_4$	9.00×10^{-10}	24
$C_2H^+ + O \rightarrow CHO^+ + C$	3.30×10^{-10}	24
$CHO^+ + C_2 \rightarrow C_2H^+ + CO$	8.30×10^{-10}	24

$C_2H^+ + CH_4 \rightarrow C_2H_2^+ + CH_3$	3.74×10^{-10}	24
$C_2H^+ + H_2 \rightarrow C_2H_2^+ + H$	1.10×10^{-9}	24
$C_2H_2^+ + CHO \rightarrow CHO^+ + C_2H_2$	$5.00\times10^{-10}\times(T_g/300)^{-0.50}$	24
$C_2H_2^+ + O \rightarrow CHO^+ + CH$	8.50×10^{-11}	24
$CHO^+ + C_2H \rightarrow C_2H_2^+ + CO$	7.80×10^{-10}	24
$C_2H_3^+ + C_2H \rightarrow C_2H_2^+ + C_2H_2$	3.30×10^{-10}	24
$C_2H_3^+ + H \rightarrow C_2H_2^+ + H_2$	6.80×10^{-11}	24
$C_2H_2^+ + CH_4 \rightarrow C_2H_3^+ + CH_3$	4.10×10^{-9}	6,7
$C_2H_2^+ + C_2H_6 \rightarrow C_2H_5^+ + C_2H_3$	1.31×10^{-10}	6,7
$C_2H_2^+ + C_2H_6 \rightarrow C_2H_4^+ + C_2H_4$	2.48×10^{-10}	24
$C_2H_2^+ + C_2H_4 \rightarrow C_2H_4^+ + C_2H_2$	4.14×10^{-10}	24
$C_2H_2^+ + C_2H_3 \rightarrow C_2H_3^+ + C_2H_2$	3.30×10^{-10}	24
$C_2H_2^+ + H_2 \rightarrow C_2H_3^+ + H$	1.00×10^{-11}	24
$CHO^+ + C_2H_2 \rightarrow C_2H_3^+ + CO$	1.40×10^{-9}	24
$C_2H_4^+ + C_2H_3 \rightarrow C_2H_3^+ + C_2H_4$	5.00×10^{-10}	6,7
$C_2H_4^+ + H \rightarrow C_2H_3^+ + H_2$	3.00×10^{-10}	24
$C_2H_3^+ + C_2H_6 \rightarrow C_2H_5^+ + C_2H_4$	2.91×10^{-10}	24
$C_2H_3^+ + C_2H_4 \rightarrow C_2H_5^+ + C_2H_2$	8.90×10^{-10}	24
$C_2H_3^+ + C_2H_3 \rightarrow C_2H_5^+ + C_2H$	5.00×10^{-10}	24
$C_2H_4^+ + O \rightarrow CHO^+ + CH_3$	8.40×10^{-11}	24
$CHO^+ + C_2H_3 \rightarrow C_2H_4^+ + CO$	$1.40\times10^{-9}\times(T_g/300)^{-0.50}$	24
$C_2H_6^+ + C_2H_4 \rightarrow C_2H_4^+ + C_2H_6$	1.15×10^{-9}	24
$C_2H_5^+ + H \rightarrow C_2H_4^+ + H_2$	1.00×10^{-11}	24
$C_2H_4^+ + C_2H_3 \rightarrow C_2H_5^+ + C_2H_2$	5.00×10^{-10}	6,7
$CHO^+ + C_2H_4 \rightarrow C_2H_5^+ + CO$	1.40×10^{-9}	24
$C_2H_6^+ + C_2H_2 \rightarrow C_2H_5^+ + C_2H_3$	2.47×10^{-10}	24
$C_2H_6^+ + H \rightarrow C_2H_5^+ + H_2$	1.00×10^{-10}	24
$CHO^+ + C_2H_5 \rightarrow C_2H_6^+ + CO$	1.40×10^{-9}	24
$H^- + H \rightarrow H_2 + e$	$2.37\times10^{-9}\times T_g^{-0.146}\times\exp(-815/T_g)$	6,7
$H^- + H \rightarrow H + H + e$	$7.47\times10^{-16}\times T_g^{1.5}\times\exp(-698/T_g)$	6,7
$H^- + M \rightarrow H + e + M$	$2.70\times10^{-10}\times(T_g/300)^{0.50}\times\exp(-5590.0/T_g)$	6,7
$H^- + O \rightarrow OH + e$	1.00×10^{-9}	24
$H^- + OH \rightarrow H_2O + e$	1.00×10^{-10}	24
$H^- + H_2O \rightarrow OH^- + H_2$	3.80×10^{-9}	6,7

$H^- + C \rightarrow CH + e$	1.00×10^{-9}	24
$H^- + CH \rightarrow CH_2 + e$	1.00×10^{-10}	24
$H^- + CH_2 \rightarrow CH_3 + e$	1.00×10^{-9}	24
$H^- + CH_3 \rightarrow CH_4 + e$	1.00×10^{-9}	24
$H^- + C_2 \rightarrow C_2H + e$	1.00×10^{-9}	24
$H^- + C_2H \rightarrow C_2H_2 + e$	1.00×10^{-9}	24
$H^- + CO \rightarrow CHO + e$	2.00×10^{-11}	24
$O^- + H \rightarrow OH + e$	5.00×10^{-10}	24
$O^- + H_2 \rightarrow H_2O + e$	7.00×10^{-10}	24
$O^- + H_2 \rightarrow OH^- + H$	3.00×10^{-11}	24
$O^- + M \rightarrow O + M + e$	$2.30\times10^{-9}\times\exp(-26000.0/T_g)$	6,7
$O^- + O \rightarrow O_2 + e$	2.30×10^{-10}	6,7
$O^- + O_2 \rightarrow O_2^- + O$	7.30×10^{-10}	24
$O^- + O_2 \rightarrow O_3 + e$	1.00×10^{-12}	6,7
$O^- + O_2 + M \rightarrow O_3^- + M$	$1.10\times10^{-30}\times(300/T_g)$	6,7
$O^- + O_2(e1) + M \rightarrow O_3^- + M$	$1.10\times10^{-30}\times(300/T_g)$	6,7
$O^- + O_2(e2) + M \rightarrow O_3^- + M$	$1.10\times10^{-30}\times(300/T_g)$	6,7
$O^- + O_2(e1) \rightarrow O_3 + e$	1.00×10^{-12}	6,7
$O^- + O_2(e2) \rightarrow O_3 + e$	1.00×10^{-12}	6,7
$O^- + O_2(e1) \rightarrow O_2^- + O$	1.00×10^{-10}	6,7
$O^- + O_3 \rightarrow O_2 + O_2 + e$	3.00×10^{-10}	6,7
$O^- + O_3 \rightarrow O_3^- + O$	5.30×10^{-10}	6,7
$O^- + C \rightarrow CO + e$	5.00×10^{-10}	24
$O^- + CH \rightarrow CHO + e$	5.00×10^{-10}	24
$O^- + CH_2 \rightarrow CH_2O + e$	5.00×10^{-10}	24
$O^- + CH_4 \rightarrow OH^- + CH_3$	1.00×10^{-10}	24
$O^- + CO \rightarrow CO_2 + e$	5.50×10^{-10}	6,7
$O^- + CO(e1) \rightarrow CO_2 + e$	5.50×10^{-10}	6,7
$O^- + CO(e2) \rightarrow CO_2 + e$	5.50×10^{-10}	6,7
$O^- + CO(e3) \rightarrow CO_2 + e$	5.50×10^{-10}	6,7
$O^- + CO(e4) \rightarrow CO_2 + e$	5.50×10^{-10}	6,7
$OH^- + CH_3 \rightarrow CH_3OH + e$	1.00×10^{-9}	24
$OH^- + CH \rightarrow CH_2O + e$	5.00×10^{-10}	24
$OH^- + C \rightarrow CHO + e$	5.00×10^{-10}	24

$OH^- + H \rightarrow H_2O + e$	1.40×10^{-9}	24
$O_2^- + M \rightarrow O_2 + M + e$	$2.70\times10^{-10}\times(T_g/300)^{0.50}\times\exp(-5590.0/T_g)$	6,7
$O_2^- + O \rightarrow O^- + O_2$	1.50×10^{-10}	6,7
$O_2^- + O \rightarrow O_3 + e$	1.50×10^{-10}	6,7
$O_2^- + O_2 \rightarrow O_2 + O_2 + e$	2.18×10^{-18}	6,7
$O_2^- + O_2(e1) \rightarrow O_2(e1) + O_2 + e$	2.18×10^{-18}	6,7
$O_2^- + O_2(e2) \rightarrow O_2(e2) + O_2 + e$	2.18×10^{-18}	6,7
$O_2^- + O_2 + M \rightarrow O_4^- + M$	$3.50\times10^{-31}\times(T_g/300)^{-1.0}$	6,7
$O_2^- + O_2(e1) + M \rightarrow O_4^- + M$	$3.50\times10^{-31}\times(T_g/300)^{-1.0}$	6,7
$O_2^- + O_2(e2) + M \rightarrow O_4^- + M$	$3.50\times10^{-31}\times(T_g/300)^{-1.0}$	6,7
$O_2^- + O_3 \rightarrow O_3^- + O_2$	4.00×10^{-10}	6,7
$O_3^- + CO_2 \rightarrow CO_3^- + O_2$	5.50×10^{-10}	6,7
$O_3^- + O \rightarrow O^- + O_3$	1.00×10^{-13}	6,7
$O_3^- + O \rightarrow O_2 + O_2 + e$	1.00×10^{-13}	6,7
$O_3^- + O \rightarrow O_2^- + O_2$	2.50×10^{-10}	6,7
$O_3^- + M \rightarrow O_3 + M + e$	2.30×10^{-11}	6,7
$O_3^- + O_2 \rightarrow O_2 + O_3 + e$	2.30×10^{-11}	6,7
$O_3^- + O_2(e1) \rightarrow O_2(e1) + O_3 + e$	2.30×10^{-11}	6,7
$O_3^- + O_2(e2) \rightarrow O_2(e2) + O_3 + e$	2.30×10^{-11}	6,7
$O_3^- + O_3 \rightarrow O_2 + O_2 + O_2 + e$	3.00×10^{-10}	6,7
$O_4^- + O \rightarrow O_3^- + O_2$	4.00×10^{-10}	6,7
$O_4^- + O \rightarrow O^- + O_2 + O_2$	3.00×10^{-10}	6,7
$O_4^- + M \rightarrow O_2^- + O_2 + M$	$1.00\times10^{-10}\times\exp(-1044.0/T_g)$	6,7
$O_4^- + CO_2 \rightarrow CO_4^- + O_2$	4.80×10^{-10}	6,7
$CH_2^- + M \rightarrow CH_2 + e + M$	$2.70\times10^{-10}\times(T_g/300)^{0.50}\times\exp(-5590.0/T_g)$	6,7
$CO_3^- + O \rightarrow O_2^- + CO_2$	8.00×10^{-11}	6,7
$CO_3^- + CO \rightarrow CO_2 + CO_2 + e$	5.00×10^{-13}	6,7
$CO_3^- + CO(e1) \rightarrow CO_2 + CO_2 + e$	5.00×10^{-13}	6,7
$CO_3^- + CO(e2) \rightarrow CO_2 + CO_2 + e$	5.00×10^{-13}	6,7
$CO_3^- + CO(e3) \rightarrow CO_2 + CO_2 + e$	5.00×10^{-13}	6,7
$CO_3^- + CO(e4) \rightarrow CO_2 + CO_2 + e$	5.00×10^{-13}	6,7
$CO_4^- + O \rightarrow CO_2 + O_2 + O^-$	1.40×10^{-11}	6,7
$CO_4^- + O \rightarrow CO_3^- + O_2$	$0.8\times1.40\times10^{-10}$	6,7
$CO_4^- + O \rightarrow O_3^- + CO_2$	1.40×10^{-11}	6,7

$CO_4^- + O_3 \rightarrow O_3^- + CO_2 + O_2$	1.30×10^{-10}	6,7

Table S10. Ion-Ion reactions

Reaction	Rate coefficients	Ref
$H^+ + H^- \rightarrow H + H$	$2.00\times10^{-7}\times(T_g/300)^{-0.50}$	6,7
$H^+ + H^- + M \rightarrow H + H + M$	$2.00\times10^{-25}\times(T_g/300)^{-2.50}$	6,7
$H^+ + O^- \rightarrow H + O$	1.93×10^{-7}	6,7
$H_2^+ + O^- \rightarrow H_2 + O$	1.93×10^{-7}	6,7
$H^+ + O_2^- \rightarrow H + O_2$	1.93×10^{-7}	6,7
$H^+ + O_2^- \rightarrow H + O + O$	1.00×10^{-7}	6,7
$H^+ + OH^- \rightarrow OH + H$	1.93×10^{-7}	6,7
$H^+ + OH^- \rightarrow H + O + H$	1.00×10^{-7}	6,7
$H^+ + CO_3^- \rightarrow H + CO_2 + O$	1.00×10^{-7}	6,7
$H^+ + CO_4^- \rightarrow H + CO_2 + O_2$	1.00×10^{-7}	6,7
$H_2^+ + H^- \rightarrow H + H + H$	1.00×10^{-7}	6,7
$H_2^+ + H^- \rightarrow H + H_2$	$2.00\times10^{-7}\times(300/T_g)^{0.5}$	6,7
$H_2^+ + H^- + M \rightarrow H + H_2 + M$	$2.00\times10^{-25}\times(T_g/300)^{-2.50}$	6,7
$H_2^+ + O^- \rightarrow H + H + O$	1.00×10^{-7}	6,7
$H_2^+ + O_2^- \rightarrow H_2 + O_2$	1.93×10^{-7}	6,7
$H_2^+ + O_2^- \rightarrow H + H + O_2$	1.00×10^{-7}	6,7
$H_2^+ + O_2^- \rightarrow H_2 + O + O$	1.00×10^{-7}	6,7
$H_2^+ + O_2^- \rightarrow H + H + O + O$	1.00×10^{-7}	6,7
$H_2^+ + OH^- \rightarrow H_2 + OH$	1.93×10^{-7}	6,7
$H_2^+ + OH^- \rightarrow OH + H + H$	1.00×10^{-7}	6,7
$H_2^+ + OH^- \rightarrow O + H + H_2$	1.00×10^{-7}	6,7
$H_2^+ + OH^- \rightarrow O + H + H + H$	1.00×10^{-7}	6,7
$H_2^+ + CO_3^- \rightarrow H_2 + CO_2 + O$	1.93×10^{-7}	6,7
$H_2^+ + CO_3^- \rightarrow H + H + CO_2 + O$	1.00×10^{-7}	6,7
$H_2^+ + CO_4^- \rightarrow H_2 + CO_2 + O_2$	1.93×10^{-7}	6,7
$H_2^+ + CO_4^- \rightarrow H + H + CO_2 + O_2$	1.00×10^{-7}	6,7
$H_3^+ + H^- \rightarrow H_2 + H + H$	1.00×10^{-7}	6,7
$H_3^+ + H^- \rightarrow H_2 + H_2$	$2.00\times10^{-7}\times(300/T_g)^{0.5}$	6,7
$H_3^+ + O^- \rightarrow O + H_2 + H$	1.00×10^{-7}	6,7
$H_3^+ + O_2^- \rightarrow O_2 + H_2 + H$	1.00×10^{-7}	6,7

$H_3^+ + O_3^- \rightarrow H_2 + H + O_3$	1.00×10^{-7}	6,7
$H_3^+ + O_3^- \rightarrow H_2 + H + O_2 + O$	1.00×10^{-7}	6,7
$H_3^+ + O_3^- + M \rightarrow H_2 + H + O_3 + M$	1.66×10^{-25}	6,7
$H_3^+ + OH^- \rightarrow OH + H + H_2$	1.00×10^{-7}	6,7
$H_3^+ + OH^- \rightarrow O + H + H + H_2$	1.00×10^{-7}	6,7
$O^+ + H^- \rightarrow H + O$	2.30×10^{-7}	6,7
$O^+ + O^- \rightarrow O + O$	$4.00\times10^{-8}\times(300/T_g)^{0.43}$	6,7
$O^+ + O^- + M \rightarrow O_2 + M$	$1.00\times10^{-25}\times(300/T_g)^{2.5}$	6,7
$O^+ + O_2^- \rightarrow O + O_2$	$2.70\times10^{-7}\times(300/T_g)^{0.5}$	6,7
$O^+ + O_2^- + M \rightarrow O_3 + M$	$1.00\times10^{-25}\times(300/T_g)^{2.5}$	6,7
$O^+ + O_3^- \rightarrow O_3 + O$	$1.00\times10^{-7}\times(300/T_g)^{0.5}$	6,7
$O^+ + OH^- \rightarrow O + H + O$	1.00×10^{-7}	6,7
$O^+ + OH^- \rightarrow OH + O$	1.93×10^{-7}	6,7
$O_2^+ + H^- \rightarrow O_2 + H$	1.93×10^{-7}	6,7
$O_2^+ + H^- \rightarrow O + O + H$	1.00×10^{-7}	6,7
$O_2^+ + O^- \rightarrow O_2 + O$	$2.60\times10^{-8}\times(300/T_g)^{0.44}$	6,7
$O_2^+ + O^- \rightarrow O + O + O$	$4.20\times10^{-7}\times(300/T_g)^{0.44}$	6,7
$O_2^+ + O^- + M \rightarrow O_3 + M$	$1.00\times10^{-25}\times(300/T_g)^{2.5}$	6,7
$O_2^+ + O_2^- \rightarrow O_2 + O_2$	$2.01\times10^{-7}\times(300/T_g)^{0.5}$	6,7
$O_2^+ + O_2^- \rightarrow O_2 + O + O$	4.20×10^{-7}	6,7
$O_2^+ + O_2^- + M \rightarrow O_2 + O_2 + M$	$1.00\times10^{-25}\times(300/T_g)^{2.5}$	6,7
$O_2^+ + O_3^- \rightarrow O_2 + O_3$	$2.00\times10^{-7}\times(300/T_g)^{0.5}$	6,7
$O_2^+ + O_3^- \rightarrow O + O + O_3$	$1.00\times10^{-7}\times(300/T_g)^{0.5}$	6,7
$O_2^+ + OH^- \rightarrow O + H + O_2$	1.00×10^{-7}	6,7
$O_2^+ + OH^- \rightarrow O + H + O + O$	1.00×10^{-7}	6,7
$O_2^+ + OH^- \rightarrow OH + O_2$	1.93×10^{-7}	6,7
$O_2^+ + OH^- \rightarrow OH + O + O$	1.00×10^{-7}	6,7
$O_2^+ + CO_3^- \rightarrow CO_2 + O_2 + O$	3.00×10^{-7}	6,7
$O_2^+ + CO_4^- \rightarrow CO_2 + O_2 + O_2$	3.00×10^{-7}	6,7
$OH^+ + H^- \rightarrow H + OH$	1.93×10^{-7}	6,7
$OH^+ + H^- \rightarrow H + O + H$	1.00×10^{-7}	6,7
$OH^+ + O^- \rightarrow O + OH$	1.93×10^{-7}	6,7
$OH^+ + O^- \rightarrow O + H + O$	1.00×10^{-7}	6,7
$OH^+ + O_2^- \rightarrow OH + O_2$	1.93×10^{-7}	6,7

$OH^+ + O_2^- \rightarrow O + H + O_2$	1.00×10^{-7}	6,7
$OH^+ + O_2^- \rightarrow OH + O + O$	1.00×10^{-7}	6,7
$OH^+ + O_2^- \rightarrow O + H + O + O$	1.00×10^{-7}	6,7
$OH^+ + OH^- \rightarrow OH + OH$	1.93×10^{-7}	6,7
$OH^+ + OH^- \rightarrow OH + O + H$	1.00×10^{-7}	6,7
$OH^+ + OH^- \rightarrow O + H + O + H$	1.00×10^{-7}	6,7
$OH^+ + CO_3^- \rightarrow OH + CO_2 + O$	1.00×10^{-7}	6,7
$OH^+ + CO_3^- \rightarrow O + H + CO_2 + O$	1.00×10^{-7}	6,7
$OH^+ + CO_4^- \rightarrow OH + CO_2 + O_2$	1.00×10^{-7}	6,7
$OH^+ + CO_4^- \rightarrow O + H + CO_2 + O_2$	1.00×10^{-7}	6,7
$H_2O^+ + H^- \rightarrow H_2O + H$	1.93×10^{-7}	6,7
$H_2O^+ + H^- \rightarrow H + H + OH$	1.00×10^{-7}	6,7
$H_2O^+ + O^- \rightarrow H_2O + O$	1.93×10^{-7}	6,7
$H_2O^+ + O^- \rightarrow OH + H + O$	1.00×10^{-7}	6,7
$H_2O^+ + O_2^- \rightarrow H_2O + O_2$	1.93×10^{-7}	6,7
$H_2O^+ + O_2^- \rightarrow OH + H + O_2$	1.00×10^{-7}	6,7
$H_2O^+ + O_2^- \rightarrow H_2O + O + O$	1.00×10^{-7}	6,7
$H_2O^+ + O_2^- \rightarrow H + OH + O + O$	1.00×10^{-7}	6,7
$H_2O^+ + OH^- \rightarrow OH + H_2O$	1.93×10^{-7}	6,7
$H_2O^+ + OH^- \rightarrow O + H + H_2O$	1.00×10^{-7}	6,7
$H_2O^+ + OH^- \rightarrow OH + OH + H$	1.00×10^{-7}	6,7
$H_2O^+ + OH^- \rightarrow O + H + OH + H$	1.00×10^{-7}	6,7
$H_2O^+ + CO_3^- \rightarrow H_2O + CO_2 + O$	1.00×10^{-7}	6,7
$H_2O^+ + CO_3^- \rightarrow OH + H + CO_2 + O$	1.00×10^{-6}	6,7
$H_2O^+ + CO_4^- \rightarrow H_2O + CO_2 + O_2$	1.00×10^{-7}	6,7
$H_2O^+ + CO_4^- \rightarrow OH + H + CO_2 + O_2$	1.00×10^{-7}	6,7
$H_3O^+ + H^- \rightarrow H + H + H_2O$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$H_3O^+ + H^- \rightarrow H_2 + OH + H$	2.30×10^{-7}	6,7
$H_3O^+ + H^- \rightarrow H_2O + H_2$	2.30×10^{-7}	6,7
$H_3O^+ + O^- \rightarrow H_2O + H + O$	1.00×10^{-7}	6,7
$H_3O^+ + O_2^- \rightarrow H_2O + H + O2$	1.00×10^{-7}	6,7
$H_3O^+ + O_2^- \rightarrow H_2O + H + O + O$	1.00×10^{-7}	6,7
$H_3O^+ + OH^- \rightarrow OH + H_2O + H$	1.00×10^{-7}	6,7
$H_3O^+ + OH^- \rightarrow O + H + H_2O + H$	1.00×10^{-7}	6,7

$H_3O^+ + CO_3^- \rightarrow H_2O + H + CO_2 + O$	1.00×10^{-7}	6,7
$H_3O^+ + CO_4^- \rightarrow H_2O + H + CO_2 + O_2$	1.00×10^{-7}	6,7
$C^+ + H^- \rightarrow C + H$	2.30×10^{-7}	6,7
$C^+ + O^- \rightarrow C + O$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C^+ + O_2^- \rightarrow C + O_2$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C^+ + OH^- \rightarrow C + OH$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CH_3^+ + H^- \rightarrow H + CH_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CH_3^+ + O^- \rightarrow O + CH_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CH_3^+ + O_2^- \rightarrow O_2 + CH_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CH_3^+ + OH^- \rightarrow OH + CH_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_2^+ + H^- \rightarrow H + C_2H_2$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_2^+ + O^- \rightarrow O + C_2H_2$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_2^+ + O_2^- \rightarrow O_2 + C_2H_2$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_2^+ + OH^- \rightarrow OH + C_2H_2$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_3^+ + H^- \rightarrow H + C_2H_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_3^+ + O^- \rightarrow O + C_2H_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_3^+ + O_2^- \rightarrow O_2 + C_2H_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$C_2H_3^+ + OH^- \rightarrow OH + C_2H_3$	$7.51\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + H^- \rightarrow H + H + CO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + H^- \rightarrow H + CHO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + O^- \rightarrow O + H + CO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + O^- \rightarrow O + CHO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + O_2^- \rightarrow O_2 + H + CO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + O_2^- \rightarrow O_2 + CHO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + OH^- \rightarrow OH + H + CO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CHO^+ + OH^- \rightarrow OH + CHO$	$3.76\times10^{-8}\times(T_g/300)^{-0.50}$	24
$CO^+ + H^- \rightarrow CO + H$	1.93×10^{-7}	6,7
$CO^+ + OH^- \rightarrow CO + OH$	1.93×10^{-7}	6,7
$CO^+ + OH^- \rightarrow CO + O + H$	1.00×10^{-7}	6,7
$CO_2^+ + H^- \rightarrow CO_2 + H$	1.93×10^{-7}	6,7
$CO_2^+ + H^- \rightarrow CO + O + H$	1.00×10^{-7}	6,7
$CO_2^+ + OH^- \rightarrow CO_2 + OH$	1.93×10^{-7}	6,7
$CO_2^+ + OH^- \rightarrow CO_2 + O + H$	1.00×10^{-7}	6,7
$CO_2^+ + OH^- \rightarrow CO + O + OH$	1.00×10^{-7}	6,7

$CO_2^+ + OH^- \rightarrow CO + O + O + H$	1.00×10^{-7}	6,7
$C_2O_2^+ + O_2^- \rightarrow CO + CO + O_2$	6.00×10^{-7}	6,7
$C_2O_2^+ + CO_3^- \rightarrow CO_2 + CO + CO + O$	5.00×10^{-7}	6,7
$C_2O_2^+ + CO_4^- \rightarrow CO_2 + CO + CO + O_2$	5.00×10^{-7}	6,7
$C_2O_3^+ + O_2^- \rightarrow CO_2 + CO + O_2$	6.00×10^{-7}	6,7
$C_2O_3^+ + CO_3^- \rightarrow CO_2 + CO_2 + CO + O$	5.00×10^{-7}	6,7
$C_2O_3^+ + CO_4^- \rightarrow CO_2 + CO_2 + CO + O_2$	5.00×10^{-7}	6,7
$C_2O_4^+ + O_2^- \rightarrow CO_2 + CO_2 + O_2$	6.00×10^{-7}	6,7
$C_2O_4^+ + CO_3^- \rightarrow CO_2 + CO_2 + CO_2 + O$	5.00×10^{-7}	6,7
$C_2O_4^+ + CO_4^- \rightarrow CO_2 + CO_2 + CO_2 + O_2$	5.00×10^{-7}	6,7

Table S11. Electron recombination reactions

Reaction	**Rate coefficients**	**Ref**
$H^+ + e \rightarrow H$	$3.50\times10^{-12}\times(300/T_e)^{0.75}$	24
$H_2^+ + e \rightarrow H + H$	$5.33\times10^{-8}\times(300/T_g)^{0.40}$	6,7
$H_2^+ + e \rightarrow H^+ + H + e$	f(σ, EEDF)	6,7
$H_2^+ + e \rightarrow H^+ + H^-$	f(σ, EEDF)	6,7
$H_2^+ + e + e \rightarrow e + H + H$	$5.26\times10^{-3}\times T_e^{-4.5}$	6,7
$H_2^+ + e + e \rightarrow H_2 + e$	$8.80\times10^{-27}\times(300/T_g)^{4.50}$	6,7
$H_3^+ + e \rightarrow H^+ + H_2 + e$	f(σ, EEDF)	6,7
$H_3^+ + e \rightarrow H^+ + H + H + e$	f(σ, EEDF)	6,7
$H_3^+ + e \rightarrow H_2 + H$	f(σ, EEDF)	6,7
$H_3^+ + e \rightarrow H + H + H$	f(σ, EEDF)	6,7
$H_3^+ + e + e \rightarrow e + H + H_2$	$5.26\times10^{-3}\times T_e^{-4.5}$	6,7
$O^+ + e + M \rightarrow O + M$	$6.00\times10^{-27}\times(300/T_e)^{1.5}$	6,7
$O^+ + e + e \rightarrow O + e$	$7.00\times10^{-20}\times(300/T_e)^{4.5}$	6,7
$O_2^+ + e + M \rightarrow O_2 + M$	1.00×10^{-26}	6,7
$O_2^+ + e \rightarrow O + O$	$6.46\times10^{-5}\times T_e^{-0.5}\times T_g^{-0.50}$	6,7
$O_4^+ + e \rightarrow O_2 + O_2$	$2.42\times10^{-5}\times T_e^{-0.50}$	6,7
$OH^+ + e \rightarrow O + H$	3.56×10^{-9}	6,7
$OH^+ + e + e \rightarrow OH + e$	7.92×10^{-29}	6,7
$OH^- + e \rightarrow e + e + H + O$	1.95×10^{-8}	6,7
$H_2O^+ + e \rightarrow O + H_2$	3.70×10^{-9}	6,7
$H_2O^+ + e \rightarrow O + H + H$	2.89×10^{-8}	6,7

$H_2O^+ + e \rightarrow OH + H$	8.14×10^{-9}	6,7
$H_2O^+ + e + e \rightarrow H_2O + e$	7.92×10^{-29}	6,7
$H_3O^+ + e \rightarrow H_2O + H$	$2.45\times10^{-8}\times(T_e/300)^{-0.83}$	6,7
$H_3O^+ + e \rightarrow OH + H_2$	$6.58\times10^{-9}\times(T_e/300)^{-0.83}$	6,7
$H_3O^+ + e \rightarrow OH + H + H$	$4.02\times10^{-9}\times(T_e/300)^{-0.83}$	6,7
$CH^+ + e \rightarrow C + H$	$3.23\times10^{-8}\times(300/T_e)^{0.42}$	6,7
$CH_2^+ + e \rightarrow CH + H$	$1.00\times10^{-8}\times(300/T_e)^{0.50}$	6,7
$CH_2^+ + e \rightarrow C + H_2$	$4.82\times10^{-9}\times(300/T_e)^{0.50}$	6,7
$CH_2^+ + e \rightarrow C + H + H$	$2.53\times10^{-8}\times(300/T_e)^{0.50}$	6,7
$CH_3^+ + e \rightarrow CH_2 + H$	$2.25\times10^{-8}\times(300/T_e)^{0.50}$	6,7
$CH_3^+ + e \rightarrow CH + H_2$	$7.88\times10^{-9}\times(300/T_e)^{0.50}$	6,7
$CH_3^+ + e \rightarrow CH + H + H$	$9.00\times10^{-9}\times(300/T_e)^{0.50}$	6,7
$CH_3^+ + e \rightarrow C + H_2 + H$	$1.69\times10^{-8}\times(300/T_e)^{0.50}$	6,7
$CH_4^+ + e \rightarrow CH_3 + H$	$1.18\times10^{-8}\times(300/T_e)^{0.50}$	6,7
$CH_4^+ + e \rightarrow CH_2 + H + H$	$2.42\times10^{-8}\times(300/T_e)^{0.50}$	6,7
$CH_4^+ + e \rightarrow CH + H_2 + H$	$1.41\times10^{-8}\times(300/T_e)^{0.50}$	6,7
$CH_5^+ + e \rightarrow CH_3 + H + H$	$2.57\times10^{-7}\times(300/T_e)^{0.30}$	6,7
$CH_5^+ + e \rightarrow CH_2 + H_2 + H$	$6.61\times10^{-8}\times(300/T_e)^{0.30}$	6,7
$CH_5^+ + e \rightarrow CH + H_2 + H_2$	$8.40\times10^{-9}\times(300/T_e)^{0.52}$	24
$CH_5^+ + e \rightarrow CH_3 + H_2$	$1.40\times10^{-8}\times(300/T_e)^{0.52}$	24
$CH_5^+ + e \rightarrow CH_4 + H$	$1.40\times10^{-8}\times(300/T_e)^{0.52}$	24
$CHO^+ + e \rightarrow H + CO$	$0.88\times2.40\times10^{-7}\times(T_e/300)^{-0.69}$	25
$CHO^+ + e \rightarrow C + OH$	$0.06\times2.40\times10^{-7}\times(T_e/300)^{-0.69}$	25
$CHO^+ + e \rightarrow CH + O$	$0.06\times2.40\times10^{-7}\times(T_e/300)^{-0.69}$	25
$CO^+ + e \rightarrow C + O$	$2.00\times10^{-7}\times(300/T_e)^{0.48}$	24
$CO_2^+ + e \rightarrow C + O_2$	$1.07\times10^{-3}\times T_e^{-0.50}/T_g$	6,7
$C_2^+ + e \rightarrow C + C$	$1.93\times10^{-6}\times T_e^{-0.50}$	6,7
$C_2H_2^+ + e \rightarrow C_2H + H$	$1.87\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2H_2^+ + e \rightarrow CH + CH$	$4.87\times10^{-9}\times(300/T_e)^{0.71}$	6,7
$C_2H_3^+ + e \rightarrow C_2H_2 + H$	$1.34\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2H_3^+ + e \rightarrow C_2H + H + H$	$2.74\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2H_4^+ + e \rightarrow C_2H_3 + H$	$8.29\times10^{-9}\times(300/T_e)^{0.71}$	6,7
$C_2H_4^+ + e \rightarrow C_2H_2 + H + H$	$3.43\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2H_4^+ + e \rightarrow C_2H + H_2 + H$	$5.53\times10^{-9}\times(300/T_e)^{0.71}$	6,7

$C_2H_5^+ + e \rightarrow C_2H_4 + H$	$7.70\times10^{-9}\times(300/T_e)^{0.71}$	6,7
$C_2H_5^+ + e \rightarrow C_2H_3 + H + H$	$1.92\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2H_5^+ + e \rightarrow C_2H_2 + H_2 + H$	$1.60\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2H_5^+ + e \rightarrow C_2H_2 + H + H + H$	$8.98\times10^{-9}\times(300/T_e)^{0.71}$	6,7
$C_2H_5^+ + e \rightarrow CH_3 + CH_2$	$9.62\times10^{-9}\times(300/T_e)^{0.71}$	6,7
$C_2H_6^+ + e \rightarrow C_2H_5 + H$	$2.19\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2H_6^+ + e \rightarrow C_2H_4 + H + H$	$3.36\times10^{-8}\times(300/T_e)^{0.71}$	6,7
$C_2O_2^+ + e \rightarrow CO + CO$	$4.00\times10^{-7}\times T_e^{-0.34}$	6,7
$C_2O_3^+ + e \rightarrow CO_2 + CO$	$3.78\times10^{-5}\times T_e^{-0.70}$	6,7
$C_2O_4^+ + e \rightarrow CO_2 + CO_2$	$2.15\times10^{-3}\times T_e^{-0.50}/T_g$	6,7
$H^- + e \rightarrow H + e + e$	f(σ, EEDF)	6,7
$OH^- + e \rightarrow OH + e + e$	f(σ, EEDF)	6,7

Table S12. Neutral-Neutral reactions

Reaction	**Rate coefficients**	**Ref**
$CH_3CHOH + O \rightarrow CH_3COOH + H$	$2.20\times10^{-10}\times(T_g/298)^{0.16}\times\exp(-4.91/(R\times T_g))$	23
$CH_3CHO + OH \rightarrow CH_3COOH + H$	$0.02\times2.49\times10^{-12}\times(T_g/298)^{0.73}\times\exp(4656/(R\times T_g))$	23
$CH_3CHO + HO_2 \rightarrow CH_3COOH + OH$	$5.00\times10^{-12}\times\exp(-49890.0/(R\times T_g))$	23
$CH_3CO_2 + M \rightarrow CH_3 + CO_2 + M$	$7.31\times10^{-9}\times\exp(-10500.0/(0.2389\times R\times T_g))$	26
$CH_3 + CO_2 + M \rightarrow CH_3CO_2 + M$	$1.25\times10^{-29}\times T_g^{1.378}\times\exp(-17520.0/(0.2389\times R\times T_g))$	26
$CH_2COOH \rightarrow CH_2CO + OH$	$1.69\times10^{18}\times T_g^{-1.18}\times\exp(-53720.0/(0.2389\times R\times T_g))$	26
$CH_2CO + OH \rightarrow CH_2COOH$	$4.32\times10^{-12}\times\exp(614.0/(0.2389\times R\times T_g))$	26
$CH_3CO + OH \rightarrow CH_3COOH$	1.66×10^{-10}	27
$CH_2COOH + H_2 \rightarrow CH_3COOH + H$	$3.37\times10^{-21}\times T_g^{3.13}\times\exp(-37843.8/(R\times T_g))$	27
$CH_2COOH + OH \rightarrow CH_3COOH + O$	$2.04\times10^{-15}\times T_g^{1.03}\times\exp(-33241.4/(R\times T_g))$	27
$CH_2COOH + H_2O \rightarrow CH_3COOH + OH$	$3.11\times10^{-19}\times T_g^{2.50}\times\exp(-73294.3/(R\times T_g))$	27
$CH_2COOH + H_2O_2 \rightarrow CH_3COOH + HO_2$	$2.64\times10^{-13}\times T_g^{0.35}\times\exp(-21175.3/(R\times T_g))$	27
$CH_2COOH + CH_4 \rightarrow CH_3COOH + CH_3$	$1.08\times10^{-14}\times T_g^{0.81}\times\exp(-25278.1/(R\times Tg))$	27
$CH_2COOH + HO_2 \rightarrow CH_3COOH + O_2$	$6.27\times10^{-12}\times T_g^{-0.24}\times\exp(11718.9/(R\times T_g))$	27
$CH_3CO_2 + H_2 \rightarrow CH_3COOH + H$	$2.24\times10^{-50}\times T_g^{11.63}\times\exp(23665.5/(R\times T_g))$	27
$CH_3CO_2 + OH \rightarrow CH_3COOH + O$	$4.46\times10^{-31}\times T_g^{5.69}\times\exp(3392.3/(R\times T_g))$	27
$CH_3CO_2 + H_2O_2 \rightarrow CH_3COOH + HO_2$	$1.77\times10^{-13}\times T_g^{0.49}\times\exp(-27927.5/(R\times T_g))$	27
$CH_3CO_2 + CH_4 \rightarrow CH_3COOH + CH_3$	$3.72\times10^{-25}\times T_g^{4.41}\times\exp(-34391.2/(R\times T_g))$	27
$CH_3CO_2 + H_2O \rightarrow CH_3COOH + OH$	$2.06\times10^{-16}\times T_g^{1.14}\times\exp(-54713.2/(R\times T_g))$	27

$CH_2OH + HO_2 \rightarrow O_2(e1) + CH3OH$	$9.47\times10^{-17}\times(T_g/298)^{3.20}\times\exp(-6800.0/(R\times T_g))$	23
$CH_3O + CH_3CHO \rightarrow CH_3OH + CH_3CO$	8.30×10^{-15}	23
$CH_3 + OH \rightarrow CH_2(S) + H_2O$	$6.37\times10^{-11}\times(T_g/298)^{-1.27}\times\exp(-1549.0/(R\times T_g))$	23
$CO + CH \rightarrow C_2HO$	$1.70\times10^{-10}\times(T_g/298)^{-0.40}$	23
$C_2H_2 + OH \rightarrow C_2HO + H_2$	1.91×10^{-13}	23
$C_2HO + O \rightarrow CO_2 + CH$	$4.90\times10^{-11}\times\exp(-4656.0/(R\times T_g))$	23
$C_2HO + H \rightarrow CH_2(S) + CO$	$2.14\times10^{-10}\times(T_g/298)^{0.16}\times\exp(-166.0/(R\times T_g))$	23
$C_2H_2 + O \rightarrow C_2HO + H$	$1.50\times10^{-11}\times\exp(-19000.0/(R\times T_g))$	23
$C_2H_2 + OH \rightarrow CH_2CO + H$	$5.31\times10^{-13}\times\exp(-840.0/(R\times T_g))$	23
$CH_2 + CO \rightarrow CH_2CO$	$1.35\times10^{-12}\times T_g^{0.50}\times\exp(-4510.0/(0.2389\times R\times T_g))$	27
$C_2H + OH \rightarrow C_2HO + H$	3.32×10^{-11}	27
$C_2H_2 + O_2 \rightarrow C_2HO + OH$	$3.32\times10^{-16}\times T_g^{1.50}\times\exp(-30100.0/(0.2389\times R\times T_g))$	27
$CH_2CO + H \rightarrow C_2HO + H_2$	$8.30\times10^{-11}\times\exp(-8000.0/(0.2389\times R\times T_g))$	27
$CH_2CO + O \rightarrow C_2HO + OH$	$1.66\times10^{-11}\times\exp(-8000.0/(0.2389\times R\times T_g))$	27
$CH_2CO + OH \rightarrow C_2HO + H_2O$	$1.25\times10^{-11}\times\exp(-2000.0/(0.2389\times R\times T_g))$	27
$CH_2O + CH \rightarrow CH_2CO + H$	$1.57\times10^{-10}\times\exp(515.0/(0.2389\times R\times T_g))$	27
$CH_3O + H \rightarrow CH_2(s) + H_2O$	$4.35\times10^{-10}/T_g^{0.23}\times\exp(-1070.0/(0.2389\times R\times T_g))$	27
$CH_2OH + H \rightarrow CH_2(s) + H_2O$	$5.45\times10^{-11}/T_g^{0.09}\times\exp(-610.0/(0.2389\times R\times T_g))$	27
$C_2H_5O + H_2 \rightarrow C_2H_5OH + H$	$4.10\times10^{-21}\times T_g^{2.74}\times\exp(-4188.0/(0.2389\times R\times T_g))$	28
$C_2H_5O + OH \rightarrow C_2H_5OH + O$	$5.79\times10^{-29}\times T_g^{4.924}\times\exp(-98.0/(0.2389\times R\times T_g))$	28
$C_2H_5O + H_2O \rightarrow C_2H_5OH + OH$	$1.22\times10^{-14}\times T_g^{0.91}\times\exp(-17210.0/(0.2389\times R\times T_g))$	28
$C_2H_5O + H_2O_2 \rightarrow C_2H_5OH + HO_2$	$1.11\times10^{-10}/T_g^{0.483}\times\exp(-7782.0/(0.2389\times R\times T_g))$	28
$C_2H_5O + CH_4 \rightarrow C_2H_5OH + CH_3$	$1.42\times10^{-22}\times T_g^{3.336}\times\exp(-9044.0/(0.2389\times R\times T_g))$	28
$C_2H_5O + CH_3OOH \rightarrow C_2H_5OH + CH_3O_2$	$2.15\times10^{-9}/T_g^{0.927}\times\exp(-6187.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + H_2 \rightarrow C_2H_5OH + H$	$7.35\times10^{-22}\times T_g^{2.97}\times\exp(-12840.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + OH \rightarrow C_2H_5OH + O$	$3.09\times10^{-22}\times T_g^{2.888}\times\exp(-8884.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + H_2O \rightarrow C_2H_5OH + OH$	$2.42\times10^{-15}\times T_g^{0.83}\times\exp(-23930.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + HO_2 \rightarrow C_2H_5OH + O_2$	$3.23\times10^{-13}\times T_g^{0.089}\times\exp(-4879.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + H_2O_2 \rightarrow C_2H_5OH + HO_2$	$1.43\times10^{-11}/T_g^{0.258}\times\exp(-9419.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + CH_3OOH \rightarrow C_2H_5OH + CH_3O_2$	$3.79\times10^{-19}\times T_g^{1.847}\times\exp(-2574.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + CH_4 \rightarrow C_2H_5OH + CH_3$	$7.47\times10^{-23}\times T_g^{3.361}\times\exp(-18590.0/(0.2389\times R\times T_g))$	28
$CH_3CHOH + C_2H_6 \rightarrow C_2H_5OH + C_2H_5$	$1.16\times10^{-13}\times\exp(-2.4/(0.2389\times R\times T_g))$	28
$C_2H_5O_2 + OH \rightarrow C_2H_5O + HO_2$	$0.75\times1.30\times10^{-10}$	23
$C_2H_4 + OH \rightarrow CH_2CH_2OH$	9.00×10^{-12}	23

$CH_2CH_2OH + O \rightarrow CH_2O + CH_2OH$	$4.59\times10^{-10}\times(T_g/298)^{0.17}\times\exp(-4.24/(R\times T_g))$	23
$CH_2CH_2OH \rightarrow C_2H_4 + OH$	$9.94\times10^{16}\times(T_g/298)^{-6.54}\times\exp(-113000.0/(R\times T_g))$	23
$CH_2CH_2OH + H \rightarrow CH_3 + CH_2OH$	1.49×10^{-10}	29
$CH_2CH_2OH + H_2 \rightarrow C_2H_5OH + H$	$6.53\times10^{-25}\times T_g^{3.826}\times\exp(-9484.0/(0.2389\times R\times T_g))$	28
$CH_2CH_2OH + OH \rightarrow C_2H_5OH + O$	$1.75\times10^{-25}\times T_g^{3.837}\times\exp(-5580.0/(0.2389\times R\times T_g))$	28
$CH_2CH_2OH + HO_2 \rightarrow C_2H_5OH + O2$	$3.64\times10^{-14}\times T_g^{0.278}\times\exp(-443.0/(0.2389\times R\times T_g))$	28
$CH_2CH_2OH + H_2O \rightarrow C_2H_5OH + OH$	$6.66\times10^{-16}\times T_g^{0.92}\times\exp(-17940.0/(0.2389\times R\times T_g))$	28
$CH_2CH_2OH + H_2O_2 \rightarrow C_2H_5OH + HO_2$	$4.78\times10^{-21}\times T_g^{2.481}\times\exp(-2827.0/(0.2389\times R\times T_g))$	28
$CH_2CH_2OH + CH_4 \rightarrow C_2H_5OH + CH_3$	$1.05\times10^{-22}\times T_g^{3.48}\times\exp(-16160.0/(0.2389\times R\times T_g))$	28
$CH_2CH_2OH + C_2H_6 \rightarrow C_2H_5OH + C_2H_5$	$1.16\times10^{-13}\times\exp(-26990.0/(0.2389\times R\times T_g))$	28
$CH_2CH_2OH + CH_3OOH \rightarrow C_2H_5OH + CH_3O_2$	$4.81\times10^{-20}\times T_g^{2.036}\times\exp(-488.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + H \rightarrow CH_2CH_2OH + H_2$	$3.12\times10^{-21}\times T_g^{3.20}\times\exp(-7150.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + O \rightarrow CH_2CH_2OH + OH$	$1.61\times10^{-21}\times T_g^{3.23}\times\exp(-4658.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + OH \rightarrow CH_2CH_2OH + H_2O$	$3.01\times10^{-13}\times T_g^{0.40}\times\exp(-717.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + O_2 \rightarrow CH_2CH_2OH + HO_2$	$3.32\times10^{-11}\times\exp(-52800.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + HO_2 \rightarrow CH_2CH_2OH + H_2O_2$	$3.95\times10^{-20}\times T_g^{2.55}\times\exp(-16490.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + CH_3 \rightarrow CH_2CH_2OH + CH_4$	$5.48\times10^{-22}\times T_g^{3.30}\times\exp(-12290.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + C_2H_5 \rightarrow CH_2CH_2OH + C_2H_6$	$8.30\times10^{-14}\times\exp(-13400.0/(0.2389\times R\times T_g))$	28
$C_2H_5OH + CH_3O_2 \rightarrow CH_2CH_2OH + CH_3OOH$	$2.04\times10^{-20}\times T_g^{2.55}\times\exp(-15750.0/(0.2389\times R\times T_g))$	28
$C_3H_7 + CH_3O_2 \rightarrow CH_3CHO + CH_3O + CH_3$	4.00×10^{-11}	23
$CH_3O_2 + CH_3CHO \rightarrow CH_3OOH + CH_3CO$	$5.00\times10^{-12}\times\exp(-6000.0/T_g)$	30
$C_3H_7 + O \rightarrow CH_3CHO + CH_3$	8.00×10^{-11}	30
$C_3H_5 + O_2 \rightarrow CH_3CHO + CHO$	1.66×10^{-13}	30
$C_2H_4 + OH \rightarrow CH_3CHO + H$	$3.95\times10^{-26}\times T_g^{3.91}\times\exp(-867.0/T_g)$	30
$C_3H_5 + O_2 \rightarrow CH_3CO + CH_2O$	$1.71\times10^{-9}\times(T_g/298)^{-3.21}\times\exp(-17980.0/(R\times T_g))$	23
$C_3H_6 + O \rightarrow CH_3CO + CH_3$	$0.19\times1.25\times10^{-12}\times(T_g/298)^{2.15}\times\exp(3330.0/(R\times T_g))$	23
$C_2H_2 + O \rightarrow CH_2CO$	2.16×10^{-13}	23
$CH_3CO + H \rightarrow CH_2CO + H_2$	$0.35\times3.32\times10^{-11}$	23
$C_3H_5 + O \rightarrow CH_3 + CH_2CO$	9.96×10^{-11}	30
$C_3H_5 + OH \rightarrow CH_3 + CH_2CO + H$	8.30×10^{-12}	30
$C_3H_5 + HO_2 \rightarrow CH_3 + CH_2CO + OH$	3.32×10^{-11}	30
$C_3H_6 + O \rightarrow CH_2CO + CH_3 + H$	$4.15\times10^{-17}\times T_g^{1.76}\times\exp(-38.2/T_g)$	30
$CH_3CHO + CH \rightarrow CH_2CO + CH_3$	1.00×10^{-10}	18
$CH_2CO + OH \rightarrow CH_3 + CO_2$	$1.12\times10^{-12}\times\exp(1013.0/(0.2389\times R\times T_g))$	18

$CH_2CHO \rightarrow CH_3CO$	$1.58\times10^{16}/(T_g/298)^{5.49}\times\exp(-193000.0/(R\times T_g))$	23
$CH_3CO \rightarrow CH_2CHO$	$3.00\times10^{15}\times\exp(-118000.0/(R\times T_g))$	23
$CH_2O + CH \rightarrow CH_2CHO$	$1.31\times10^{-12}\times(T_g/298)^{0.38}\times\exp(3610.0/(R\times T_g))$	23
$C_2H_3 + O \rightarrow CH_2CHO$	$5.50\times10^{-11}\times(T_g/298)^{0.20}\times\exp(1790.0/(R\times T_g))$	23
$C_2H_3 + O_2 \rightarrow CH_2CHO + O$	$2.13\times10^{-11}/(T_g/298)^{0.03}\times\exp(-18950.0/(R\times T_g))$	23
$C_2H_3 + OH \rightarrow CH_2CHO + H$	$5.58\times10^{-12}\times(T_g/298)^{0.26}\times\exp(1820.0/(R\times T_g))$	23
$C_2H_4 + O \rightarrow CH_2CHO + H$	$3.36\times10^{-12}\times(T_g/298)^{0.95}\times\exp(-7220.0/(R\times T_g))$	23
$C_3H_5 + O_2 \rightarrow CH_2CHO + CH_2O$	$4.21\times10^{-14}\times(T_g/298)^{0.37}\times\exp(-70750.0/(R\times T_g))$	23
$CH_3CHO + H \rightarrow CH_2CHO + H_2$	$2.13\times10^{-13}\times(T_g/298)^{3.10}\times\exp(-21780.0/(R\times T_g))$	23
$CH_3CHO + O \rightarrow CH_2CHO + OH$	$2.49\times10^{-11}\times\exp(-20920.0/(R\times T_g))$	23
$CH_3CHO + O_2 \rightarrow CH_2CHO + HO_2$	$3.32\times10^{-10}\times\exp(-203000.0/(R\times T_g))$	23
$CH_3CHO + OH \rightarrow CH_2CHO + H_2O$	$2.66\times10^{-11}\times\exp(-8370.0/(R\times T_g))$	23
$CH_3CHO + HO_2 \rightarrow CH_2CHO + H_2O_2$	$1.66\times10^{-12}\times\exp(-58580.0/(R\times T_g))$	23
$CH_3CHO + CH_3 \rightarrow CH_2CHO + CH_4$	$9.96\times10^{-12}\times\exp(-46020.0/(R\times T_g))$	23
$C_2H_3 + HO_2 \rightarrow CH_2CHO + OH$	1.66×10^{-11}	18
$CH_3CHO + CH_2 \rightarrow CH_2CHO + CH_3$	$2.76\times10^{-12}\times\exp(-3517.0/(0.2389\times R\times T_g))$	18
$CH_2CHO \rightarrow CH_3 + CO$	$6.51\times10^{34}/T_g^{6.87}\times\exp(-47197.0/(0.2389\times R\times T_g))$	18
$CH_2CHO \rightarrow CH_2CO + H$	$1.32\times10^{34}/T_g^{6.57}\times\exp(-49460.0/(0.2389\times R\times T_g))$	18
$CH_2CHO + H \rightarrow CH_3CHO$	1.66×10^{-10}	18
$CH_2CHO + H \rightarrow CH_2CO + H_2$	3.32×10^{-11}	18
$CH_2CHO + OH \rightarrow H_2O + CH_2CO$	1.99×10^{-11}	18
$CH_2CHO + H \rightarrow CH_3 + CHO$	8.29×10^{-11}	18
$CH_2CHO + O \rightarrow CH_2O + CHO$	8.30×10^{-11}	18
$CH_2CHO + OH \rightarrow CHO + CH_2OH$	5.00×10^{-10}	18
$CH_2CHO + O_2 \rightarrow CO + CH_2O + OH$	$4.45\times10^{-7}/T_g^{1.84}\times\exp(-6530.0/(0.2389\times R\times T_g))$	18
$CH_3O + C_2H_4 \rightarrow CH_3OH + C_2H_3$	$1.99\times10^{-13}\times\exp(-3400.0/T_g)$	30
$CH_2OH + OH \rightarrow CH_3OH + O$	$3.89\times10^{-21}\times T_g^{2.59}\times\exp(-7956.0/(0.2389\times R\times T_g))$	31
$CH_2OH + HO_2 \rightarrow CH_3OH + O_2$	$2.06\times10^{-12}/T_g^{0.24}\times\exp(3501.0/(0.2389\times R\times T_g))$	31
$CH_2OH + CH_3OOH \rightarrow CH_3OH + CH_3O_2$	$3.90\times10^{-10}/T_g^{1.03}\times\exp(-2404.0/(0.2389\times R\times T_g))$	31
$CH_2OH + C_2H_5OOH \rightarrow CH_3OH + C_2H_5O_2$	$3.90\times10^{-10}/T_g^{1.03}\times\exp(-2408.0/(0.2389\times R\times T_g))$	31
$CH_3O_2 + OH \rightarrow CH_3O + HO_2$	$0.90\times2.80\times10^{-10}$	23
$CH_2(S) + H_2O_2 \rightarrow CH_3O + OH$	5.00×10^{-11}	29
$C_2H_5 + OH \rightarrow CH_2OH + CH_3$	4.98×10^{-11}	29
$CH_3O + CH_3OOH \rightarrow CH_3OH + OH + CH_2O$	$2.49\times10^{-13}\times\exp(-6500.0/(0.2389\times R\times T_g))$	32

$CH_3O + C_2H_5OOH \rightarrow CH_3CHO + OH + CH_3OH$	$1.05\times10^{-12}\times\exp(-5500.0/(0.2389\times R\times T_g))$	32
$CH_2OH + C_2H_5OOH \rightarrow CH_3CHO + OH + CH_3OH$	$6.97\times10^{-13}\times\exp(-13600.0/(0.2389\times R\times T_g))$	32
$CH_3O + CH_2CO \rightarrow CH_3OH + C_2HO$	$5.69\times10^{-19}\times T_g^{2.00}\times\exp(-6416.99/(0.2389\times R\times T_g))$	33
$CH_3O + CH_3CHO \rightarrow CH_3OH + CH_2CHO$	$2.13\times10^{-19}\times T_g^{2.00}\times\exp(-3702.80/(0.2389\times R\times T_g))$	33
$CH_2OH + CH_2CO \rightarrow CH_3OH + C_2HO$	$3.76\times10^{-19}\times T_g^{2.00}\times\exp(-17077.95/(0.2389\times R\times T_g))$	33
$CH_2OH + CH_3CHO \rightarrow CH_3OH + CH_2CHO$	$1.41\times10^{-19}\times T_g^{2.00}\times\exp(-13176.14/(0.2389\times R\times T_g))$	33
$CH_2CHO + H \rightarrow CH_3CO + H$	8.30×10^{-12}	34
$CH_3CHO + CH_2CHO \rightarrow CH_3CHO + CH_3CO$	4.15×10^{-17}	40
$CH_3CHO + CHO \rightarrow CH_3CO + CH_2O$	$1.30\times10^{-10}\times\exp(-8440.0/(0.2389\times R\times T_g))$	35
$C_2H_3 + O_2 \rightarrow CH_2CO + OH$	$1.94\times10^{-21}\times T_g^{2.43}\times\exp(-7074.00/(0.2389\times R\times T_g))$	33
$C_2HO + H_2O_2 \rightarrow CH_2CO + HO_2$	$5.69\times10^{-20}\times T_g^{2.00}\times\exp(-1926.22/(0.2389\times R\times T_g))$	33
$C_2HO + CH_2O \rightarrow CH_2CO + CHO$	$5.69\times10^{-19}\times T_g^{2.00}\times\exp(-4161.68/(0.2389\times R\times T_g))$	33
$C_2HO + CH_3CHO \rightarrow CH_3CO + CH_2CO$	$4.26\times10^{-19}\times T_g^{2.00}\times\exp(-4416.11/(0.2389\times R\times T_g))$	33
$CH_2CHO + O \rightarrow CH_2CO + OH$	$3.32\times10^{-11}\times\exp(-4000.0/(0.2389\times R\times T_g))$	34
$CH_2CHO + O_2 \rightarrow CH_2CO + HO_2$	2.33×10^{-13}	34
$C_2HO + H_2 \rightarrow CH_2CO + H$	$1.08\times10^{-12}\times\exp(-840.11/(0.2389\times R\times T_g))$	36
$C_2HO + H_2O \rightarrow CH_2CO + OH$	$2.34\times10^{-13}\times\exp(-9994.98/(0.2389\times R\times T_g))$	36
$CH_3 + CO \rightarrow CH_2CO + H$	$3.99\times10^{-12}\times\exp(-40200.05/(0.2389\times R\times T_g))$	36
$CH_2 + CO_2 \rightarrow CH_2CO + O$	$6.21\times10^{-12}\times\exp(-53690.01/(0.2389\times R\times T_g))$	36
$C_3H_7 + HO_2 \rightarrow CH_3CHO + CH_3 + OH$	3.99×10^{-11}	35
$C_3H_6 + OH \rightarrow CH_3CHO + CH_3$	$2.32\times10^{-12}\times\exp(1040.0/(0.2389\times R\times T_g))$	37
$C_2H_3 + CH_3O_2 \rightarrow CH_2CHO + CH_3O$	3.99×10^{-11}	41
$CH_2 + O_2 \rightarrow COOH + H$	$0.15\times4.10\times10^{-11}\times\exp(-6240.0/(R\times T_g))$	23
$CO + OH \rightarrow COOH$	$9.34\times10^{-13}\times(T_g/298)^{-3.50}\times\exp(-5478.0/(R\times T_g))$	23
$CH_2O + OH \rightarrow COOH + H_2$	$1.40\times10^{-12}\times(T_g/298)^{1.63}\times\exp(-4410.0/(R\times T_g))$	23
$CH_3 + COOH \rightarrow CH_3COOH$	$5.81\times10^{-11}\times(T_g/298)^{0.10}$	23
$CH_3O_2 + H \rightarrow CH_4 + O_2$	$1.17\times10^{-11}\times(T_g/298)^{1.02}\times\exp(-69450.0/(R\times T_g))$	23
$CH_3O_2 + OH \rightarrow CH_3OH + O_2(e1)$	$3.53\times10^{-12}/(T_g/298)^{1.17}\times\exp(570.0/(R\times T_g))$	23
$CH_3O_2 + HO_2 \rightarrow CH_3OH + O_3$	$4.10\times10^{-13}\times\exp(6570.0/(R\times T_g))$	23
$CH_2OH + H \rightarrow CH_3OH$	$1.29\times10^{-9}/T_g^{0.247}\times\exp(-1668.0/(0.2389\times R\times T_g))$	26
$O_2 + CH_2OH \rightarrow CH_2O + HO_2$	1.40×10^{-12}	23
$CH_3 + O_2 \rightarrow CH_3O_2$	6.11×10^{-14}	23
$HCOOH + OH \rightarrow H_2O + HCOO$	$7.86\times10^{-16}\times(T_g/298)^{5.59}\times\exp(9910.0/(R\times T_g))$	23
$H + COOH \rightarrow HCOOH$	9.50×10^{-10}	38

$CH_3 + CH_3 \rightarrow C_2H_6$	8.00×10^{-11}	23
$CH_3 + O \rightarrow CH_2O + H$	1.00×10^{-10}	23
$CH_3 + OH \rightarrow CH_3OH$	$7.70\times10^{-13}\times(T_g/298)^{2.08}\times\exp(7360.0/(R\times T_g))$	23
$H + O_2 + M \rightarrow HO_2 + M$	1.20×10^{-32}	23
$CH_3 + COOH \rightarrow CH_4 + CO_2$	$0.40\times5.80\times10^{-11}\times\exp(-60.0/(0.2389\times R\times T_g))$	39
$CH_3 + COOH \rightarrow CH_2CO + H_2O$	$0.60\times5.80\times10^{-11}\times\exp(-60.0/(0.2389\times R\times T_g))$	39
$COOH + CO \rightarrow CO_2 + CHO$	1.00×10^{-15}	23
$CH_3O + H \rightarrow CH_3OH$	$4.04\times10^{-12}\times T_g^{0.52}\times\exp(-50.0/(0.2389\times R\times T_g))$	27
$CH_3 + O \rightarrow CHO + H_2$	$0.40\times1.70\times10^{-10}$	23
$CH_2(S) + O \rightarrow H + CO + H$	7.48×10^{-11}	29
$CH_2(S) + O \rightarrow CO + H_2$	7.48×10^{-11}	29
$CH_2(S) + O_2 \rightarrow CO + OH + H$	4.65×10^{-11}	29
$CH_2(S) + O_2 \rightarrow CO + H_2O$	1.99×10^{-11}	29
$C_2H_4 + H \rightarrow C_2H_5$	$1.25\times10^{-11}\times(T_g/298)^{1.07}\times\exp(-6067.0/(R\times T_g))$	42
$C_2H_4 + O \rightarrow CHO + CH_3$	$1.50\times10^{-12}\times(T_g/298)^{1.55}\times\exp(-1788.0/(R\times T_g))$	41
$CH_3 + CH_3CO \rightarrow C_2H_6 + CO$	$0.38\times1.43\times10^{-10}$	43
$C_2H_5 + C_2H_3 \rightarrow C_2H_6 + C_2H_2$	$0.37\times6.50\times10^{-11}$	44,45
$CH_3 + M \rightarrow CH + H_2 + M$	$6.97\times10^{-9}\times\exp(-345.0\times10^3/(R\times T_g))$	6,7
$CH_2 + M \rightarrow C + H_2 + M$	$2.16\times10^{-10}\times\exp(-247.0\times10^3/(R\times T_g))$	6,7
$CH_2 + M \rightarrow CH + H + M$	$6.64\times10^{-9}\times\exp(-348.0\times10^3/(R\times T_g))$	6,7
$C + H_2 + M \rightarrow CH_2 + M$	6.89×10^{-32}	6,7
$CH + M \rightarrow C + H + M$	$3.16\times10^{-10}\times\exp(-280.0\times10^3/(R\times T_g))$	6,7
$C_2 + M \rightarrow C + C + M$	$2.49\times10^{-8}\times\exp(-595.0\times10^3/(R\times T_g))$	6,7
$C + CO + M \rightarrow C_2O + M$	6.31×10^{-32}	6,7
$H_2 + M \rightarrow H + H + M$	$1.88\times10^{-8}\times(T_g/298)^{-1.1}\times\exp(-437.0\times10^3/(R\times T_g))$	6,7
$H + H + M \rightarrow H_2 + M$	$6.04\times10^{-33}\times(T_g/298)^{-1.00}$	6,7
$O + CO + M \rightarrow CO_2 + M$	$8.20\times10^{-34}\times\exp(-1510.0/T_g)\times2.000$	6,7
$O_3 + M \rightarrow O_2 + O + M$	$4.12\times10^{-10}\times\exp(-11430.0/T_g)$	6,7
$O + O_2 + M \rightarrow O_3 + M$	$5.51\times10^{-34}\times(T_g/298)^{-2.6}$	6,7
$O_2 + M \rightarrow O + O + M$	$3.00\times10^{-6}\times T_g^{-1}\times\exp(-5.938\times10^4/T_g)$	6,7
$O + O + M \rightarrow O_2 + M$	$5.21\times10^{-35}\times\exp(900.0/T_g)$	6,7
$CO_2 + M \rightarrow CO + O + M$	$6.06\times10^{-10}\times\exp(-5.2525\times10^4/T_g)$	6,7
$O + C + M \rightarrow CO + M$	$2.14\times10^{-29}\times(T_g/300)^{-3.08}\times\exp(-2114.0/T_g)$	6,7
$H + O + M \rightarrow OH + M$	$4.36\times10^{-32}\times(T_g/300)^{-1.00}$	6,7

$CH + CO + M \rightarrow C_2HO + M$	$4.15\times10^{-30}\times(T_g/298)^{-1.90}$	6,7
$H + CO + M \rightarrow CHO + M$	4.80×10^{-35}	6,7
$H + OH + M \rightarrow H_2O + M$	$4.38\times10^{-30}\times(T_g/298)^{-2.0}$	6,7
$OH + OH + M \rightarrow H_2O_2 + M$	$6.04\times10^{-31}\times(T_g/298)^{-3.0}$	6,7
$OH + M \rightarrow O + H + M$	$4.00\times10^{-9}\times\exp(-416\times10^3/(R\times T_g))$	6,7
$H_2O + M \rightarrow OH + H + M$	$5.80\times10^{-9}\times\exp(-440.0\times10^3/(R\times T_g))$	6,7
$CH_3OH + M \rightarrow CH_3 + OH + M$	$3.32\times10^{-7}\times\exp(-286.0\times10^3/(R\times T_g))$	6,7
$H_2O_2 + M \rightarrow OH + OH + M$	$2.03\times10^{-3}\times(T_g/298)^{-4.86}\times\exp(-223\times10^3/(R\times T_g))$	6,7
$HO_2 + M \rightarrow H + O_2 + M$	$2.41\times10^{-8}\times(T_g/298)^{-1.18}\times\exp(-203.0\times10^3/(R\times T_g))$	6,7
$CHO + M \rightarrow H + CO + M$	$2.61\times10^{-10}\times\exp(-65.93\times10^3/(R\times T_g))$	6,7
$CH_3OH + M \rightarrow CH_2OH + H + M$	$2.16\times10^{-8}\times\exp(-279.0\times10^3/(R\times T_g))$	6,7
$CH_3O_2 + M \rightarrow CH_3 + O_2 + M$	$2.03\times(T_g/298)^{-10.0}\times\exp(-139.0\times10^3/(R\times T_g))$	6,7
$C_2HO + M \rightarrow CO + CH + M$	$1.08\times10^{-8}\times\exp(-246.0\times10^3/(R\times T_g))$	6,7
$C_2H_2 + H \rightarrow C_2H_3$	$9.13\times10^{-12}\times\exp(-1.01\times10^4/(R\times T_g))$	46
$C_3H_8 \rightarrow C_3H_7 + H$	$1.58\times10^{16}\times\exp(-408.0\times10^3/(R\times T_g))$	6,7
$C_3H_7 \rightarrow C_3H_6 + H$	$1.09\times10^{13}\times(T_g/298)^{0.17}\times\exp(-1.49\times10^5/(R\times T_g))$	6,7
$C_3H_6 \rightarrow C_3H_5 + H$	$2.50\times10^{15}\times\exp(-363.0\times10^3/(R\times T_g))$	6,7
$C_3H_6 \rightarrow CH_3 + C_2H_3$	$1.18\times10^{18}\times(T_g/298)^{-1.20}\times\exp(-409.0\times10^3/(R\times T_g))$	6,7
$C_2H_2 + CH_3 \rightarrow C_3H_5$	$1.00\times10^{-12}\times\exp(-32.26\times10^3/(R\times T_g))$	6,7
$C_2H_3 + H \rightarrow C_2H_4$	2.01×10^{-10}	47
$C_2H + H \rightarrow C_2H_2$	3.01×10^{-10}	6,7
$C_2H_4 \rightarrow C_2H_3 + H$	$2.00\times10^{16}\times\exp(-4.61\times10^5/(R\times T_g))$	48
$CH_4 \rightarrow CH_3 + H$	$3.72\times10^{15}\times\exp(-4.34\times10^5/(R\times T_g))$	41
$C_2H_5 \rightarrow C_2H_4 + H$	$6.86\times10^{12}\times(T_g/298)^{0.95}\times\exp(-1.55\times10^5/(R\times T_g))$	42
$C_2H_3 \rightarrow C_2H_2 + H$	$2.00\times10^{14}\times\exp(-1.66\times10^5/(R\times T_g))$	49
$C_2H_2 \rightarrow C_2H + H$	$2.63\times10^{15}\times\exp(-5.19\times10^5/(R\times T_g))$	41
$C_3H_8 \rightarrow C_2H_5 + CH_3$	$2.78\times10^{18}\times(T_g/298)^{-1.80}\times\exp(-3.71\times10^5/(R\times T_g))$	50
$C_2H_4 \rightarrow C_2H_2 + H_2$	$9.75\times10^{13}\times(T_g/298)^{0.44}\times\exp(-3.72\times10^5/(R\times T_g))$	41
$CH_3CO \rightarrow CO + CH_3$	$3.87\times10^{13}\times(T_g/298)^{0.63}\times\exp(-70.70\times10^3/(R\times T_g))$	6,7
$CHO + H \rightarrow CH_2O$	$7.77\times10^{-14}\times\exp(1.90\times10^4/(R\times T_g))$	51
$CH_2OH \rightarrow CH_2O + H$	$1.16\times10^{17}\times(T_g/298)^{-7.11}\times\exp(-1.84\times10^5/(R\times T_g))$	52
$CH_3O \rightarrow CH_2O + H$	$1.69\times10^{14}\times(T_g/298)^{0.39}\times\exp(-1.10\times10^5/(R\times T_g))$	42
$HCOOH \rightarrow CO + H2O$	$9.12\times10^{12}\times\exp(-2.52\times10^5/(R\times T_g))$	6,7
$C_2H_5O + H \rightarrow C_2H_5OH$	$8.32\times10^{-11}\times(T_g/298)^{0.44}\times\exp(-54.04/(R\times T_g))$	53

$C_2H_5OH \rightarrow C_2H_5 + OH$	$1.34\times10^{17}\times(T_g/298)^{-2.16}\times\exp(-4.04\times10^5/(R\times T_g))$	54
$C_2H_5OH \rightarrow C_2H_5O + H$	$1.53\times10^{16}\times(T_g/298)^{0.31}\times\exp(-4.24\times10^5/(R\times T_g))$	53
$C_2H_5OOH \rightarrow C_2H_5O + OH$	$4.00\times10^{15}\times\exp(-1.80\times10^5/(R\times T_g))$	55
$CH_3CHOH + H \rightarrow C_2H_5OH$	$8.43\times10^{-11}\times(T_g/298)^{0.06}\times\exp(-1829.0/(R\times T_g))$	53
$CH_3CHOH \rightarrow CH_3CHO + H$	$1.20\times10^{15}\times(T_g/298)^{-5.19}\times\exp(-1.49\times10^5/(R\times T_g))$	56
$CH_3CHOH \rightarrow CH_2O + CH_3$	$1.49\times10^{13}\times(T_g/298)^{-3.59}\times\exp(-1.45\times10^5/(R\times T_g))$	56
$C_2H_5OH \rightarrow CH_3CHOH + H$	$1.57\times10^{16}\times(T_g/298)^{-0.28}\times\exp(-3.93\times10^5/(R\times T_g))$	53
$CH_3 \rightarrow CH_2 + H$	$1.90\times10^{16}\times(T_g/298)^{0.09}\times\exp(-4.59\times10^5/(R\times T_g))$	57
$CH_3 + C_2H_3 \rightarrow C_3H_6$	1.20×10^{-10}	44
$C_2H_5 + H \rightarrow C_2H_6$	$2.55\times10^{-10}\times(T_g/298)^{0.16}$	58
$C_3H_7 + H \rightarrow C_3H_8$	6.00×10^{-11}	59
$C_3H_6 + H \rightarrow C_3H_7$	$6.64\times10^{-12}\times\exp(-1.10\times10^4/(R\times T_g))$	46
$C_3H_5 + H \rightarrow C_3H_6$	$2.64\times10^{-10}\times(T_g/298)^{0.18}\times\exp(524/(R\times T_g))$	60
$C_2H_6 \rightarrow CH_3 + CH_3$	$1.54\times10^{18}\times(T_g/298)^{-2.14}\times\exp(-3.80\times10^5/(R\times T_g))$	55
$CH_2CO \rightarrow CO + CH_2$	$3.00\times10^{14}\times\exp(-2.97\times10^5/(R\times T_g))$	46
$C_2H_5 + OH \rightarrow C_2H_5OH$	1.28×10^{-10}	61
$C_2H_5OH \rightarrow C_2H_4 + H_2O$	$6.91\times10^{16}\times(T_g/298)^{-3.68}\times\exp(-2.96\times10^5/(R\times T_g))$	62
$C_2H_5OH \rightarrow CH_3 + CH_2OH$	$7.91\times10^{24}\times(T_g/298)^{-10.59}\times\exp(-4.22\times10^5/(R\times T_g))$	62
$C_2H_5 + O_2 \rightarrow C_2H_5O_2$	$1.09\times10^{-7}\times(T_g/298)^{-10.30}\times\exp(-2.54\times10^4/(R\times T_g))$	63
$C_2H_5O_2 \rightarrow C_2H_5 + O_2$	$5.30\times10^{15}\times(T_g/298)^{-0.83}\times\exp(-1.43\times10^5/(R\times T_g))$	64
$CH_3 + CO \rightarrow CH_3CO$	$8.40\times10^{-13}\times\exp(-2.88\times10^4/(R\times T_g))$	55
$C_2H_4 + O \rightarrow CH_2O + CH_2$	$8.08\times10^{-13}\times(T_g/298)^{1.99}\times\exp(-1.20\times10^4/(R\times T_g))$	65
$CH_2O + O_2 \rightarrow CHO + HO_2$	$3.40\times10^{-11}\times\exp(-1.63\times10^5/(R\times T_g))$	41
$C_2H_4 + OH \rightarrow C_2H_3 + H_2O$	$2.29\times10^{-13}\times(T_g/298)^{2.74}\times\exp(-9271.0/(R\times T_g))$	66
$C_2H_3 + H \rightarrow C_2H_2 + H_2$	3.32×10^{-11}	46
$CH_3 + C_2H_5 \rightarrow C_2H_4 + CH_4$	$1.88\times10^{-12}\times(T_g/298)^{-0.50}$	41
$H + CH_3CHO \rightarrow H_2 + CH_3CO$	$6.64\times10^{-11}\times\exp(-1.76\times10^4/(R\times T_g))$	46
$CH + C_2H_5 \rightarrow C_3H_5 + H$	$3.80\times10^{-8}\times T_g^{-0.859}\times\exp(-33.5/T_g)$	67
$CH_3CO + H \rightarrow CH_3CHO$	$1.50\times10^{-10}\times(T_g/298)^{0.16}$	68
$C_2H_5O_2 \rightarrow CH_3CHO + OH$	$7.27\times10^{10}\times(T_g/298)^{2.63}\times\exp(-1.55\times10^5/(R\times T_g))$	69
$C_2H_3 + OH \rightarrow CH_3CHO$	5.00×10^{-11}	41
$C_2H_5 + O_2 \rightarrow CH_3CHO + OH$	$1.00\times10^{-13}\times\exp(-2.87\times10^4/(R\times T_g))$	41
$CH_3CHO + H \rightarrow CO + H_2 + CH_3$	$4.88\times10^{-13}\times(T_g/298)^{2.75}\times\exp(-4041.0/(R\times T_g))$	70
$CH_3CHO + O_2 \rightarrow CH_3CO + HO_2$	$5.00\times10^{-11}\times\exp(-1.64\times10^5/(R\times T_g))$	49

$CH_3CHO + C_2H_3 \rightarrow C_2H_4 + CH_3CO$	$1.35\times10^{-13}\times\exp(-1.54\times10^{4}/(R\times T_g))$	71
$CH + H_2O \rightarrow CH_2OH$	$9.48\times10^{-12}\times\exp(3159.0/(R\times T_g))$	72
$C_2H_3 + OH \rightarrow CH_3CO + H$	$2.92\times10^{-11}\times(T_g/298)^{-1.01}\times\exp(-1621.0/(R\times T_g))$	68
$CH_3CO + O_2 \rightarrow CO_2 + CH_3O$	$7.37\times10^{-14}\times\exp(4506.0/(R\times T_g))$	73
$CH_3O + HO_2 \rightarrow CH_3OH + O_2$	4.70×10^{-11}	74
$C_2H_3 + OH \rightarrow CH_3 + CHO$	$2.88\times10^{-10}\times(T_g/298)^{-1.85}\times\exp(-4166.0/(R\times T_g))$	68
$CO + CH_3O \rightarrow CH_2O + CHO$	3.26×10^{-33}	75
$CH_3CHO + H \rightarrow CH_4 + CHO$	8.80×10^{-14}	76
$CHO + H \rightarrow O + CH_2$	$6.61\times10^{-11}\times\exp(-4.29\times10^{5}/(R\times T_g))$	77
$CHO \rightarrow CO + H$	$2.00\times10^{5}\times\exp(-1.10\times10^{5}/(R\times T_g))$	78
$CH_3 + CHO \rightarrow CH_3CHO$	3.01×10^{-11}	41
$CH_3 + O_2 \rightarrow CH_2O + OH$	$2.81\times10^{-13}\times\exp(-4.14\times10^{4}/(R\times T_g))$	23,79
$CH_3 + OH \rightarrow CH_2O + H_2$	$2.59\times10^{-13}\times(T_g/298)^{-0.53}\times\exp(-4.52\times10^{4}/(R\times T_g))$	80
$CH_3O + CH_3CO \rightarrow CH_2O + CH_3CHO$	1.00×10^{-11}	41
$CH_3O_2 + HO_2 \rightarrow CH_2O + H_2O + O_2$	$1.60\times10^{-15}\times\exp(-1.44\times10^{4}/(R\times T_g))$	81
$CH_3O_2 + CH_2OH \rightarrow CH_2O + CH_3OOH$	$4.75\times10^{-18}\times(T_g/298)^{2.69}\times\exp(1.43\times10^{4}/(R\times T_g))$	82
$CH_3O_2 \rightarrow CH_2O + OH$	$5.86\times10^{10}\times(T_g/298)^{2.98}\times\exp(-1.63\times10^{5}/(R\times T_g))$	83
$C_3H_5 + O_2 \rightarrow CH_2O + C_2H_2 + OH$	$3.37\times10^{-10}\times(T_g/298)^{-2.70}\times\exp(-1.05\times10^{5}/(R\times T_g))$	84
$CH_3OH + OH \rightarrow CH_2O + H_2O + H$	$1.10\times10^{-12}\times(T_g/298)^{1.44}\times\exp(-474.0/(R\times T_g))$	85
$CH_2O + H \rightarrow CH_2OH$	$2.41\times10^{-13}\times(T_g/298)^{-1.40}\times\exp(-2.17\times10^{4}/(R\times T_g))$	52
$CH_2O + H \rightarrow CH_3O$	$3.99\times10^{-11}\times\exp(-1.72\times10^{4}/(R\times T_g))$	42
$CH_3 + C_2H_3 \rightarrow C_3H_5 + H$	$2.59\times10^{-9}\times(T_g/298)^{-1.25}\times\exp(-3.21\times10^{4}/(R\times T_g))$	86
$CH + CH \rightarrow C_2H_2$	1.99×10^{-10}	87
$CH + H_2 \rightarrow CH_3$	$2.01\times10^{-10}\times(T_g/298)^{0.15}$	88
$C_2H_4 + O \rightarrow CH_3CO + H$	$9.11\times10^{-13}\times(T_g/298)^{-0.48}\times\exp(-8192.0/(R\times T_g))$	65
$C_2H_4 + O_2 \rightarrow C_2H_3 + HO_2$	$7.01\times10^{-11}\times\exp(-2.41\times10^{5}/(R\times T_g))$	41
$CH_2CO + CH_2 \rightarrow C_2H_4 + CO$	2.09×10^{-10}	89
$CH_2CO + H \rightarrow CH_3CO$	$2.66\times10^{-11}\times\exp(-6279.0/(R\times T_g))$	90
$CH_2CO + OH \rightarrow CH_2O + CHO$	4.65×10^{-11}	91
$CH_2CO + CH_3 \rightarrow CO + C_2H_5$	$9.54\times10^{-14}\times(T_g/298)^{2.29}\times\exp(-4.45\times10^{4}/(R\times T_g))$	92
$CH_2CO + CH_2 \rightarrow CH_3 + C_2HO$	1.00×10^{-17}	93
$CH_2CO + CH_3 \rightarrow CH_4 + C_2HO$	$5.94\times10^{-14}\times(T_g/298)^{3.38}\times\exp(-4.40\times10^{4}/(R\times T_g))$	92
$CH_3CO + CH_3CO \rightarrow CH_3CHO + CH_2CO$	1.49×10^{-11}	94
$CH_3 + CH_3CO \rightarrow CH_4 + CH_2CO$	1.01×10^{-11}	94

$C_2H_4 + O \rightarrow CH_2CO + H_2$	3.82×10^{-14}	95
$CH_3CHO \rightarrow CH_2CO + H_2$	$3.00\times10^{14}\times\exp(-3.51\times10^{5}/(R\times T_g))$	96
$CH_3CO \rightarrow CH_2CO + H$	$6.54\times10^{-4}\times(T_g/298)^{-4.34}\times\exp(-1.94\times10^{5}/(R\times T_g))$	97
$C_2H_3 + OH \rightarrow CH_2CO + H_2$	$2.22\times10^{-12}\times(T_g/298)^{-1.52}\times\exp(-3018.0/(R\times T_g))$	68
$OH + C_2HO \rightarrow CH_2CO + O$	$1.76\times10^{-13}\times(T_g/298)^{1.99}\times\exp(-4.72\times10^{4}/(R\times T_g))$	98
$CH_3 + CH_2OH \rightarrow C_2H_5OH$	2.01×10^{-11}	99
$C_2H_5OH + H \rightarrow C_2H_5 + H_2O$	$9.80\times10^{-13}\times\exp(-1.45\times10^{4}/(R\times T_g))$	100
$C_2H_5OH + OH \rightarrow C_2H_5O + H_2O$	$1.67\times10^{-14}\times(T_g/298)^{3.15}\times\exp(2380.0/(R\times T_g))$	101
$C_2H_5O \rightarrow CH_3CHO + H$	$1.07\times10^{14}\times(T_g/298)^{-0.69}\times\exp(-9.30\times10^{4}/(R\times T_g))$	42
$C_2H_5O + C_2H_5O_2 \rightarrow CH_3CHO + C_2H_5OOH$	1.54×10^{-11}	102
$C_2H_5O + H \rightarrow CH_3 + CH_2OH$	$1.23\times10^{-10}\times(T_g/298)^{0.70}\times\exp(-1447.0/(R\times T_g))$	53
$C_2H_5O + H \rightarrow C_2H_5 + OH$	$1.25\times10^{-12}\times(T_g/298)^{1.27}\times\exp(-1305.0/(R\times T_g))$	53
$C_2H_5O + H \rightarrow CH_3CHO + H_2$	$8.69\times10^{-12}\times(T_g/298)^{1.15}\times\exp(-2819.0/(R\times T_g))$	53
$C_2H_5O + H \rightarrow C_2H_4 + H_2O$	$9.69\times10^{-12}\times(T_g/298)^{-0.81}\times\exp(-2985.0/(R\times T_g))$	53
$C_2H_5O + H \rightarrow CH_2O + CH_4$	$3.88\times10^{-16}\times(T_g/298)^{2.21}\times\exp(752.0/(R\times T_g))$	53
$CH_3CHO + H \rightarrow C_2H_5O$	$1.33\times10^{-11}\times\exp(-2.68\times10^{4}/(R\times T_g))$	42
$CH_2O + CH_3 \rightarrow C_2H_5O$	$4.98\times10^{-13}\times\exp(-2.65\times10^{4}/(R\times T_g))$	42
$C_2H_5 + O_2 \rightarrow C_2H_5O + O$	$6.14\times10^{-12}\times(T_g/298)^{-0.20}\times\exp(-1.17\times10^{5}/(R\times T_g))$	63
$C_2H_5 + HO_2 \rightarrow C_2H_5O + OH$	4.98×10^{-11}	63
$C_2H_5O_2 + O_3 \rightarrow C_2H_5O + O_2 + O_2$	9.27×10^{-18}	103
$C_2H_5O_2 + C_2H_5O_2 \rightarrow CH_3CHO + C_2H_5O + HO_2$	$1.21\times10^{-15}\times\exp(-0.07/(R\times T_g))$	104
$C_2H_5O_2 \rightarrow C_2H_5O + O$	$1.78\times10^{15}\times(T_g/298)^{-0.09}\times\exp(-2.58\times10^{5}/(R\times T_g))$	105
$C_2H_5 + O \rightarrow C_2H_5O$	$6.31\times10^{-11}\times(T_g/298)^{0.03}\times\exp(1648.0/(R\times T_g))$	106
$C_2H_5 + O_3 \rightarrow C_2H_5O + O_2$	3.32×10^{-14}	107
$CH_3CHOH + O_2 \rightarrow CH_3CHO + HO_2$	1.90×10^{-11}	108
$CH_3CHOH + O \rightarrow CH_3CHO + OH$	3.16×10^{-10}	108
$CH_3CHOH + H \rightarrow CH_3CHO + H_2$	3.32×10^{-11}	108
$CH_3CHOH + H \rightarrow CH_3 + CH_2OH$	$8.99\times10^{-10}\times(T_g/298)^{-0.89}\times\exp(-1.21\times10^{4}/(R\times T_g))$	53
$CH_3CHOH + H \rightarrow C_2H_5O + H$	$9.31\times10^{-16}\times(T_g/298)^{2.94}\times\exp(-3.55\times10^{4}/(R\times T_g))$	53
$CH_3CHOH + H \rightarrow C_2H_5 + OH$	$3.55\times10^{-11}\times(T_g/298)^{-0.83}\times\exp(-2.01\times10^{4}/(R\times T_g))$	53
$CH_3CHOH + H \rightarrow C_2H_4 + H_2O$	$2.63\times10^{-10}\times(T_g/298)^{-3.02}\times\exp(-1.19\times10^{4}/(R\times T_g))$	53
$CH_3CHOH + H \rightarrow CH_2O + CH_4$	$8.73\times10^{-17}\times(T_g/298)^{2.10}\times\exp(-890.0/(R\times T_g))$	53
$C_2H_5OH + H \rightarrow H_2 + CH_3CHOH$	$1.64\times10^{-11}\times(T_g/298)^{-0.33}\times\exp(-2.25\times10^{4}/(R\times T_g))$	101
$C_2H_5OH + OH \rightarrow CH_3CHOH + H_2O$	$5.28\times10^{-11}\times(T_g/298)^{0.54}\times\exp(420.0/(R\times T_g))$	6

$C_2H_5OH + HO_2 \rightarrow CH_3CHOH + H_2O_2$	$3.09\times10^{-10}\times(T_g/298)^{-1.81}\times\exp(-6.89\times10^{4}/(R\times T_g))$	101
$C_2H_5OH + CH_3 \rightarrow CH_4 + CH_3CHOH$	$8.87\times10^{-15}\times(T_g/298)^{3.37}\times\exp(-3.29\times10^{4}/(R\times T_g))$	101
$C_2H_5OH + O \rightarrow CH_3CHOH + OH$	1.03×10^{-13}	110
$C_2H_5O \rightarrow CH_3CHOH$	$1.87\times(T_g/298)^{12.40}\times\exp(-1.77\times10^{4}/(R\times T_g))$	111
$CH_3CHO + H \rightarrow CH_3CHOH$	$8.02\times10^{-13}\times(T_g/298)^{2.20}\times\exp(-3.14\times10^{4}/(R\times T_g))$	70
$CH_3CHO + HO_2 \rightarrow CH_3CHOH + O_2$	$4.19\times10^{-10}\times(T_g/298)^{-1.80}\times\exp(-1.09\times10^{5}/(R\times T_g))$	95
$C_2H_6 + C_2H_5O_2 \rightarrow C_2H_5 + C_2H_5OOH$	$2.87\times10^{-14}\times(T_g/298)^{3.76}\times\exp(-71960/(R\times T_g))$	6,7
$C_2H_5 + CH_3O_2 \rightarrow CH_3O + C_2H_5O$	4.00×10^{-11}	6,7
$C_2H_4 + O_3 \rightarrow CH_2O + CO_2 + H_2$	7.06×10^{-19}	6,7
$C_2H_4 + O_3 \rightarrow CH_2O + CO + H_2O$	7.06×10^{-19}	6,7
$C_2H_4 + O_3 \rightarrow CH_2O + CH_2O + O$	2.69×10^{-19}	6,7
$H_2 + C_2 \rightarrow C_2H_2$	$1.77\times10^{-10}\times\exp(-1470.0/T_g)$	6,7
$CH_4 + C_2 \rightarrow C_2H + CH_3$	$5.50\times10^{-11}\times\exp(-297.0/T_g)$	6,7
$CH_3 + C_2H_5OH \rightarrow CH_4 + C_2H_5O$	3.11×10^{-19}	6,7
$CH_3 + O_3 \rightarrow CH_3O + O_2$	9.79×10^{-31}	6,7
$H + C_2H_5OH \rightarrow H_2 + C_2H_5O$	$1.33\times10^{-20}\times(T_g/298)^{10.58}\times\exp(18650/(R\times T_g))$	6,7
$H + O_3 \rightarrow OH + O_2$	2.83×10^{-11}	6,7
$CO_2 + C \rightarrow CO + CO$	1.00×10^{-15}	6,7
$O_3 + CO \rightarrow CO_2 + O_2$	4.00×10^{-25}	6,7
$O_2 + C_2O \rightarrow CO_2 + CO$	3.30×10^{-13}	6,7
$O + C_2O \rightarrow CO + CO$	9.51×10^{-11}	6,7
$O + O_3 \rightarrow O_2 + O_2$	$8.00\times10^{-12}\times\exp(-2056.0/T_g)$	6,7
$O_3 + O_2 \rightarrow O + O_2 + O_2$	2.29×10^{-26}	6,7
$O_3 + O_3 \rightarrow O + O_2 + O_3$	5.18×10^{-26}	6,7
$O_3 + O \rightarrow O + O_2 + O$	3.14×10^{-27}	6,7
$O_3 + OH \rightarrow O_2 + HO_2$	$3.76\times10^{-13}\times(T_g/298)^{1.99}\times\exp(-5.02\times10^{3}/(R\times T_g))$	6,7
$O_3 + HO_2 \rightarrow O_2 + O_2 + OH$	$1.97\times10^{-16}\times(T_g/298)^{4.57}\times\exp(5.76\times10^{3}/(R\times T_g))$	6,7
$O_3 + CH_3O_2 \rightarrow CH_3O + O_2 + O_2$	1.00×10^{-17}	6,7
$O + C_2H_5OOH \rightarrow C_2H_5O_2 + OH$	$3.30\times10^{-11}\times\exp(-19.87\times10^{3}/(R\times T_g))$	6,7
$O_2 + C_2H_5O \rightarrow CH_3CHO + HO_2$	8.12×10^{-15}	6,7
$HO_2 + C_2H_5O_2 \rightarrow C_2H_5OOH + O_2$	7.63×10^{-12}	6,7
$C_2H_5O_2 + C_2H_5O_2 \rightarrow C_2H_5OH + CH_3CHO + O_2$	2.43×10^{-14}	6,7
$C_2H_5O_2 + C_2H_5O_2 \rightarrow C_2H_5O + C_2H_5O + O_2$	3.97×10^{-14}	6,7
$CH_3CHO + HO_2 \rightarrow C_2H_5O + O_2$	$6.96\times10^{-14}\times(T_g/298)^{1.62}\times\exp(-64.6\times10^{3}/(R\times T_g))$	6,7

$OH + C_2H_5OOH \rightarrow H_2O + C_2H_5O_2$	$1.61\times10^{-13}\times(T_g/298)^{2.32}\times\exp(6.66\times10^{3}/(R\times T_g))$	6,7
$CH_3 + C_3H_7 \rightarrow C_2H_5 + C_2H_5$	$3.20\times10^{-11}\times T_g^{-0.32}$	6,7
$C_3H_7 + H \rightarrow CH_3 + C_2H_5$	$6.74\times10^{-18}\times T_g^{2.19}\times\exp(-890.0/(1.987\times T_g))$	6,7
$C_2H_4 + CH_2 \rightarrow C_3H_6$	$5.30\times10^{-12}\times\exp(-2660/T_g)$	6,7
$CH + C_2H_6 \rightarrow C_3H_6 + H$	3.00×10^{-11}	6,7
$C_2H_6 + CH \rightarrow C_2H_4 + CH_3$	$1.79\times10^{-10}\times\exp(263.0/(1.987\times T_g))$	6,7
$C_2H_6 + CH_2 \rightarrow C_2H_5 + CH_3$	$9.00\times10^{-33}\times T_g^{6.4162}$	6,7
$C_2H_4 + H_2 \rightarrow C_2H_6$	$4.75\times10^{-16}\times\exp(-180000.0/(R\times T_g))$	6,7
$CH_3 + C_2H_5 \rightarrow C_2H_6 + CH_2$	$3.00\times10^{-44}\times T_g^{9.0956}$	6,7
$C_2H_5 + C_2H_3 \rightarrow C_2H_4 + C_2H_4$	$0.68\times6.50\times10^{-11}$	6,7
$CH + CH_3 \rightarrow C_2H_3 + H$	4.98×10^{-11}	6,7
$C_2H + C_2H \rightarrow C_2H_2 + C_2$	3.01×10^{-12}	6,7
$C + CH_2 \rightarrow CH + CH$	$2.69\times10^{-12}\times\exp(-196.0\times10^{3}/(R\times T_g))$	6,7
$C + CH_2 \rightarrow H + C_2H$	8.30×10^{-11}	6,7
$C_2H + H \rightarrow H_2 + C_2$	$5.99\times10^{-11}\times\exp(-118000/(R\times T_g))$	6,7
$H_2 + C_2 \rightarrow C_2H + H$	$1.10\times10^{-10}\times\exp(-33.26\times10^{3}/(R\times T_g))$	6,7
$CH_4 + CH_2 \rightarrow CH_3 + CH_3$	3.01×10^{-19}	6,7
$CH_4 + CH \rightarrow C_2H_4 + H$	9.97×10^{-11}	6,7
$CH_4 + C_2H_5 \rightarrow C_2H_6 + CH_3$	$2.51\times10^{-15}\times(T_g/298)^{4.14}\times\exp(-52550/(R\times T_g))$	6,7
$CH_4 + C_2H_3 \rightarrow C_2H_4 + CH_3$	$2.13\times10^{-14}\times(T_g/298)^{4.02}\times\exp(-22860/(R\times T_g))$	6,7
$CH_4 + C_2H \rightarrow C_2H_2 + CH_3$	$3.01\times10^{-12}\times\exp(-2080/(R\times T_g))$	6,7
$CH_4 + C_3H_7 \rightarrow C_3H_8 + CH_3$	$3.54\times10^{-16}\times(T_g/298)^{4.02}\times\exp(-45480/(R\times T_g))$	6,7
$CH_4 + C_3H_5 \rightarrow C_3H_6 + CH_3$	$1.71\times10^{-14}\times(T_g/298)^{3.40}\times\exp(-97280/(R\times T_g))$	6,7
$CH_4 + H \rightarrow CH_3 + H_2$	$9.86\times10^{-13}\times(T_g/298)^{3.0}\times\exp(-36670.0/(R\times T_g))$	6,7
$CH_3 + CH_3 \rightarrow C_2H_5 + H$	$1.46\times10^{-11}\times(T_g/298)^{0.1}\times\exp(-44400/(R\times T_g))$	6,7
$CH_3 + CH_2 \rightarrow C_2H_4 + H$	7.01×10^{-11}	6,7
$CH_3 + C_2H_6 \rightarrow C_2H_5 + CH_4$	$1.74\times10^{-16}\times(T_g/298)^{6.0}\times\exp(-25280/(R\times T_g))$	6,7
$CH_3 + C_2H_4 \rightarrow C_2H_3 + CH_4$	$6.91\times10^{-12}\times\exp(-46.56\times10^{3}/(R\times T_g))$	6,7
$CH_3 + C_2H_3 \rightarrow C_2H_2 + CH_4$	3.00×10^{-11}	6,7
$CH_3 + C_2H_2 \rightarrow CH_4 + C_2H$	$3.01\times10^{-13}\times\exp(-72340/(R\times T_g))$	6,7
$CH_3 + C_3H_8 \rightarrow C_3H_7 + CH_4$	$1.61\times10^{-15}\times(T_g/298)^{3.65}\times\exp(-29930/(R\times T_g))$	6,7
$CH_3 + C_3H_7 \rightarrow C_3H_6 + CH_4$	$3.07\times10^{-12}\times(T_g/298)^{-0.32}$	6,7
$CH_3 + C_3H_6 \rightarrow C_3H_5 + CH_4$	$1.68\times10^{-15}\times(T_g/298)^{3.50}\times\exp(-23780/(R\times T_g))$	6,7
$CH_3 + H_2 \rightarrow CH_4 + H$	$2.52\times10^{-14}\times(T_g/298)^{3.12}\times\exp(-36420.0/(R\times T_g))$	6,7

$CH_3 + H \rightarrow CH_2 + H_2$	$1.00\times10^{-10}\times\exp(-63190/(R\times T_g))$	6,7
$CH_2 + CH_2 \rightarrow C_2H_2 + H + H$	$3.32\times10^{-10}\times\exp(-45.98\times10^3/(R\times T_g))$	6,7
$CH_2 + C_2H_5 \rightarrow C_2H_4 + CH_3$	3.01×10^{-11}	6,7
$CH_2 + C_2H_3 \rightarrow C_2H_2 + CH_3$	3.01×10^{-11}	6,7
$CH_2 + C_2H \rightarrow C_2H_2 + CH$	3.01×10^{-11}	6,7
$CH_2 + C_3H_8 \rightarrow C_3H_7 + CH_3$	$1.61\times10^{-15}\times(T_g/298)^{3.65}\times\exp(-29930/(R\times T_g))$	6,7
$CH_2 + C_3H_7 \rightarrow C_2H_4 + C_2H_5$	3.01×10^{-11}	6,7
$CH_2 + C_3H_7 \rightarrow C_3H_6 + CH_3$	3.01×10^{-12}	6,7
$CH_2 + C_3H_6 \rightarrow C_3H_5 + CH_3$	$1.20\times10^{-12}\times\exp(-25940/(R\times T_g))$	6,7
$CH_2 + H_2 \rightarrow CH_3 + H$	5.00×10^{-15}	6,7
$CH_2 + H \rightarrow CH + H_2$	$1.00\times10^{-11}\times\exp(7480/(R\times T_g))$	6,7
$CH + H_2 \rightarrow CH_2 + H$	$1.48\times10^{-11}\times(T_g/298)^{1.79}\times\exp(-6.98\times10^3/(R\times T_g))$	6,7
$CH + H \rightarrow C + H_2$	$1.31\times10^{-10}\times\exp(-6700/(R\times T_g))$	6,7
$C + H_2 \rightarrow CH + H$	$6.64\times10^{-10}\times\exp(-97.28\times10^3/(R\times T_g))$	6,7
$C_2H_6 + C_2H_3 \rightarrow C_2H_5 + C_2H_4$	$1.46\times10^{-13}\times(T_g/298)^{3.30}\times\exp(-43900/(R\times T_g))$	6,7
$C_2H_6 + C_2H \rightarrow C_2H_2 + C_2H_5$	5.99×10^{-12}	6,7
$C_2H_6 + C_3H_7 \rightarrow C_3H_8 + C_2H_5$	$1.19\times10^{-15}\times(T_g/298)^{3.82}\times\exp(-37830/(R\times T_g))$	6,7
$C_2H_6 + C_3H_5 \rightarrow C_3H_6 + C_2H_5$	$5.71\times10^{-14}\times(T_g/298)^{3.30}\times\exp(-83060/(R\times T_g))$	6,7
$C_2H_6 + H \rightarrow C_2H_5 + H_2$	$1.23\times10^{-11}\times(T_g/298)^{1.50}\times\exp(-31010/(R\times T_g))$	6,7
$C_2H_5 + C_2H_5 \rightarrow C_2H_6 + C_2H_4$	2.41×10^{-12}	6,7
$C_2H_5 + C_2H_4 \rightarrow C_2H_6 + C_2H_3$	$5.83\times10^{-14}\times(T_g/298)^{3.13}\times\exp(-75330/(R\times T_g))$	6,7
$C_2H_5 + C_2H_2 \rightarrow C_2H_6 + C_2H$	$4.50\times10^{-13}\times\exp(-98110/(R\times T_g))$	6,7
$C_2H_5 + C_2H \rightarrow C_2H_4 + C_2H_2$	3.01×10^{-12}	6,7
$C_2H_5 + C_3H_8 \rightarrow C_2H_6 + C_3H_7$	$1.61\times10^{-15}\times(T_g/298)^{3.65}\times\exp(-38250/(R\times T_g))$	6,7
$C_2H_5 + C_3H_7 \rightarrow C_3H_8 + C_2H_4$	1.91×10^{-12}	6,7
$C_2H_5 + C_3H_7 \rightarrow C_3H_6 + C_2H_6$	2.41×10^{-12}	6,7
$C_2H_5 + C_3H_6 \rightarrow C_3H_5 + C_2H_6$	$1.69\times10^{-15}\times(T_g/298)^{3.50}\times\exp(-27770/(R\times T_g))$	6,7
$C_2H_5 + C_3H_5 \rightarrow C_3H_6 + C_2H_4$	$4.30\times10^{-12}\times\exp(550/(R\times T_g))$	6,7
$C_2H_5 + H_2 \rightarrow C_2H_6 + H$	$4.12\times10^{-15}\times(T_g/298)^{3.60}\times\exp(-35340/(R\times T_g))$	6,7
$C_2H_5 + H \rightarrow CH_3 + CH_3$	5.99×10^{-11}	6,7
$C_2H_5 + H \rightarrow C_2H_4 + H_2$	3.01×10^{-12}	6,7
$C_2H_4 + C_2H \rightarrow C_2H_2 + C_2H_3$	1.40×10^{-10}	6,7
$C_2H_4 + H \rightarrow C_2H_3 + H_2$	$4.00\times10^{-12}\times(T_g/298)^{2.53}\times\exp(-51220/(R\times T_g))$	6,7
$C_2H_3 + C_2H_3 \rightarrow C_2H_4 + C_2H_2$	1.60×10^{-12}	6,7

$C_2H_3 + C_2H \rightarrow C_2H_2 + C_2H_2$	1.60×10^{-12}	6,7
$C_2H_3 + C_3H_8 \rightarrow C_2H_4 + C_3H_7$	$1.46\times10^{-13}\times(T_g/298)^{3.30}\times\exp(-43900/(R\times T_g))$	6,7
$C_2H_3 + C_3H_7 \rightarrow C_3H_8 + C_2H_2$	2.01×10^{-12}	6,7
$C_2H_3 + C_3H_7 \rightarrow C_3H_6 + C_2H_4$	2.01×10^{-12}	6,7
$C_2H_3 + C_3H_6 \rightarrow C_3H_5 + C_2H_4$	$1.68\times10^{-15}\times(T_g/298)^{3.50}\times\exp(-19620/(R\times T_g))$	6,7
$C_2H_3 + C_3H_5 \rightarrow C_3H_6 + C_2H_2$	8.00×10^{-12}	6,7
$C_2H_3 + H_2 \rightarrow C_2H_4 + H$	$1.61\times10^{-13}\times(T_g/298)^{2.63}\times\exp(-35750/(R\times T_g))$	6,7
$C_2H_2 + H \rightarrow C_2H + H_2$	$1.00\times10^{-10}\times\exp(-93120/(R\times T_g))$	6,7
$C_2H + C_3H_8 \rightarrow C_2H_2 + C_3H_7$	5.99×10^{-12}	6,7
$C_2H + C_3H_7 \rightarrow C_3H_6 + C_2H_2$	1.00×10^{-11}	6,7
$C_2H + C_3H_6 \rightarrow C_3H_5 + C_2H_2$	5.99×10^{-12}	6,7
$C_2H + H_2 \rightarrow C_2H_2 + H$	$8.95\times10^{-13}\times(T_g/298)^{2.57}\times\exp(-1080/(R\times T_g))$	6,7
$C_3H_8 + C_3H_5 \rightarrow C_3H_6 + C_3H_7$	$5.71\times10^{-14}\times(T_g/298)^{3.30}\times\exp(-83060/(R\times T_g))$	6,7
$C_3H_8 + H \rightarrow C_3H_7 + H_2$	$4.23\times10^{-12}\times(T_g/298)^{2.54}\times\exp(-28270/(R\times T_g))$	6,7
$C_3H_7 + C_3H_7 \rightarrow C_3H_6 + C_3H_8$	2.81×10^{-12}	6,7
$C_3H_7 + C_3H_6 \rightarrow C_3H_5 + C_3H_8$	$1.69\times10^{-15}\times(T_g/298)^{3.50}\times\exp(-27770/(R\times T_g))$	6,7
$C_3H_7 + C_3H_5 \rightarrow C_3H_6 + C_3H_6$	$2.41\times10^{-12}\times\exp(550/(R\times T_g))$	6,7
$C_3H_7 + H_2 \rightarrow C_3H_8 + H$	$3.19\times10^{-14}\times(T_g/298)^{2.84}\times\exp(-38250/(R\times T_g))$	6,7
$C_3H_7 + H \rightarrow C_3H_6 + H_2$	3.01×10^{-12}	6,7
$C_3H_6 + H \rightarrow C_3H_5 + H_2$	$4.40\times10^{-13}\times(T_g/298)^{2.50}\times\exp(-10390/(R\times T_g))$	6,7
$C_3H_5 + H_2 \rightarrow C_3H_6 + H$	$1.39\times10^{-13}\times(T_g/298)^{2.38}\times\exp(-79490/(R\times T_g))$	6,7
$CH_4 + O \rightarrow CH_3 + OH$	$8.32\times10^{-12}\times(T_g/298)^{1.56}\times\exp(-35503/(R\times T_g))$	6,7
$CH_3 + OH \rightarrow CH_4 + O$	$3.22\times10^{-14}\times(T_g/298)^{2.20}\times\exp(-18.62\times10^{3}/(R\times T_g))$	6,7
$CH_3 + O \rightarrow CO + H_2 + H$	$0.46\times1.70\times10^{-10}$	6,7
$CH_2 + O \rightarrow CO + H_2$	5.53×10^{-11}	6,7
$CH_2 + O \rightarrow CO + H + H$	8.29×10^{-11}	6,7
$CH_2 + O_2 \rightarrow CO_2 + H_2$	$2.99\times10^{-11}\times(T_g/298)^{-3.30}\times\exp(-11.97\times10^{3}/(R\times T_g))$	6,7
$CH_2 + O_2 \rightarrow CO + H_2O$	1.42×10^{-12}	6,7
$CH_2 + O_2 \rightarrow CH_2O + O$	5.39×10^{-13}	6,7
$CH + O \rightarrow CO + H$	6.59×10^{-11}	6,7
$CH + O_2 \rightarrow CO_2 + H$	1.20×10^{-11}	6,7
$CH + O_2 \rightarrow CO + OH$	8.00×10^{-12}	6,7
$CH + O_2 \rightarrow CHO + O$	8.00×10^{-12}	6,7
$CH + O_2 \rightarrow CO + H + O$	1.20×10^{-11}	6,7

$C_2H_6 + O \rightarrow C_2H_5 + OH$	$8.54\times10^{-12}\times(T_g/298)^{1.50}\times\exp(-24280/(R\times T_g))$	6,7
$C_2H_5 + O \rightarrow CH_3CHO + H$	8.80×10^{-11}	6,7
$C_2H_5 + O \rightarrow CH_2O + CH_3$	6.90×10^{-11}	6,7
$C_2H_5 + O \rightarrow C_2H_4 + OH$	$6.31\times10^{-12}\times(T_g/298)^{0.03}\times\exp(1.65\times10^{3}/(R\times T_g))$	6,7
$C_2H_5 + O_2 \rightarrow C_2H_4 + HO_2$	3.80×10^{-15}	6,7
$C_2H_3 + O \rightarrow C_2H_2 + OH$	$5.50\times10^{-12}\times(T_g/298)^{0.20}\times\exp(1.79\times10^{3}/(R\times T_g))$	6,7
$C_2H_3 + O \rightarrow CO + CH_3$	1.25×10^{-11}	6,7
$C_2H_3 + O \rightarrow CHO + CH_2$	1.25×10^{-11}	6,7
$C_2H_3 + O \rightarrow CH_2CO + H$	1.60×10^{-10}	6,7
$C_2H_3 + O_2 \rightarrow CH_2O + CHO$	9.00×10^{-12}	6,7
$C_2H_2 + O \rightarrow CH_2 + CO$	$3.49\times10^{-12}\times(T_g/298)^{1.50}\times\exp(-7.07\times10^{3}/(R\times T_g))$	6,7
$C_2H + O \rightarrow CH + CO$	1.69×10^{-11}	6,7
$C_2H + O_2 \rightarrow CHO + CO$	3.00×10^{-11}	6,7
$C_2H + O_2 \rightarrow C_2HO + O$	1.00×10^{-12}	6,7
$C_3H_8 + O \rightarrow C_3H_7 + OH$	$1.37\times10^{-12}\times(T_g/298)^{2.68}\times\exp(-15548/(R\times T_g))$	6,7
$H_2 + O \rightarrow OH + H$	$3.44\times10^{-13}\times(T_g/298)^{2.67}\times\exp(-26274/(R\times T_g))$	6,7
$H + O_2 \rightarrow OH + O$	$3.07\times10^{-13}\times(T_g/298)^{2.70}\times\exp(-26190.0/(R\times T_g))$	6,7
$CH_4 + OH \rightarrow CH_3 + H_2O$	$4.16\times10^{-13}\times(T_g/298)^{2.18}\times\exp(-10240/(R\times T_g))$	6,7
$CH_4 + HO_2 \rightarrow CH_3 + H_2O_2$	$3.01\times10^{-13}\times\exp(-77740/(R\times T_g))$	6,7
$CH_4 + CHO \rightarrow CH_3 + CH_2O$	$1.36\times10^{-13}\times(T_g/298)^{2.85}\times\exp(-93954/(R\times T_g))$	6,7
$CH_4 + CH_3O \rightarrow CH_3OH + CH_3$	$2.61\times10^{-13}\times\exp(-37000/(R\times T_g))$	6,7
$CH_4 + CH_3O_2 \rightarrow CH_3 + CH_3OOH$	$3.01\times10^{-13}\times\exp(-77320/(R\times T_g))$	6,7
$CH_3 + H_2O \rightarrow CH_4 + OH$	$1.20\times10^{-14}\times(T_g/298)^{2.90}\times\exp(-62190/(R\times T_g))$	6,7
$CH_3 + OH \rightarrow CH_2 + H_2O$	$1.20\times10^{-10}\times\exp(-11640/(R\times T_g))$	6,7
$CH_3 + OH \rightarrow CH_2OH + H$	$1.54\times10^{-9}\times(T_g/298)^{-1.80}\times\exp(-33.76\times10^{3}/(R\times T_g))$	6,7
$CH_3 + OH \rightarrow CH_3O + H$	$2.57\times10^{-12}\times(T_g/298)^{-0.23}\times\exp(-58.28\times10^{3}/(R\times T_g))$	6,7
$CH_3 + HO_2 \rightarrow CH_3O + OH$	$7.68\times10^{-12}\times(T_g/298)^{0.27}\times\exp(2.88\times10^{3}/(R\times T_g))$	6,7
$CH_3 + HO_2 \rightarrow CH_4 + O_2$	5.99×10^{-12}	6,7
$CH_3 + CH_2O \rightarrow CH_4 + CHO$	$1.60\times10^{-16}\times(T_g/298)^{6.10}\times\exp(-8230/(R\times T_g))$	6,7
$CH_3 + CHO \rightarrow CH_4 + CO$	2.01×10^{-10}	6,7
$CH_3 + CH_3O \rightarrow CH_4 + CH_2O$	4.00×10^{-11}	6,7
$CH_3 + CH_3CHO \rightarrow CH_4 + CH_3CO$	$2.97\times10^{-16}\times(T_g/298)^{5.64}\times\exp(-10310/(R\times T_g))$	6,7
$CH_3 + CH_3O_2 \rightarrow CH_3O + CH_3O$	4.00×10^{-11}	6,7
$CH_2 + CO_2 \rightarrow CH_2O + CO$	3.90×10^{-14}	6,7

$CH_2 + H_2O \rightarrow CH_3 + OH$	1.60×10^{-16}	6,7
$CH_2 + OH \rightarrow CH_2O + H$	3.01×10^{-11}	6,7
$CH_2 + HO_2 \rightarrow CH_2O + OH$	3.00×10^{-11}	6,7
$CH_2 + CH_2O \rightarrow CH_3 + CHO$	1.00×10^{-14}	6,7
$CH_2 + CHO \rightarrow CH_3 + CO$	3.01×10^{-11}	6,7
$CH_2 + CH_3O \rightarrow CH_3 + CH_2O$	3.01×10^{-11}	6,7
$CH_2 + CH_3O_2 \rightarrow CH_2O + CH_3O$	3.01×10^{-11}	6,7
$CH + CO_2 \rightarrow CHO + CO$	9.68×10^{-13}	6,7
$CH + CO_2 \rightarrow CO + CO + H$	9.68×10^{-13}	6,7
$C_2H_6 + OH \rightarrow C_2H_5 + H_2O$	$3.97\times10^{-13}\times(T_g/298)^{2.0}\times\exp(-2519/(R\times T_g))$	6,7
$C_2H_6 + HO_2 \rightarrow C_2H_5 + H_2O_2$	$4.90\times10^{-13}\times\exp(-65520/(R\times T_g))$	6,7
$C_2H_6 + CHO \rightarrow C_2H_5 + CH_2O$	$4.18\times10^{-13}\times(T_g/298)^{2.72}\times\exp(-76330/(R\times T_g))$	6,7
$C_2H_6 + CH_3O \rightarrow C_2H_5 + CH_3OH$	$4.00\times10^{-13}\times\exp(-29680/(R\times T_g))$	6,7
$C_2H_6 + CH_3O_2 \rightarrow C_2H_5 + CH_3OOH$	$4.90\times10^{-13}\times\exp(-62520/(R\times T_g))$	6,7
$C_2H_5 + H_2O \rightarrow C_2H_6 + OH$	$2.06\times10^{-14}\times(T_g/298)^{1.44}\times\exp(-84810/(R\times T_g))$	6,7
$C_2H_5 + OH \rightarrow C_2H_4 + H_2O$	4.00×10^{-11}	6,7
$C_2H_5 + HO_2 \rightarrow C_2H_6 + O_2$	5.00×10^{-13}	6,7
$C_2H_5 + HO_2 \rightarrow C_2H_4 + H_2O_2$	5.00×10^{-13}	6,7
$C_2H_5 + CH_2O \rightarrow C_2H_6 + CHO$	$8.19\times10^{-14}\times(T_g/298)^{2.81}\times\exp(-24530/(R\times T_g))$	6,7
$C_2H_5 + CHO \rightarrow C_2H_6 + CO$	2.01×10^{-10}	6,7
$C_2H_5 + CH_3O \rightarrow C_2H_6 + CH_2O$	4.00×10^{-11}	6,7
$C_2H_4 + HO_2 \rightarrow CH_3CHO + OH$	$1.00\times10^{-14}\times\exp(-33260/(R\times T_g))$	6,7
$C_2H_3 + H_2O \rightarrow C_2H_4 + OH$	$1.20\times10^{-14}\times(T_g/298)^{2.9}\times\exp(-62190/(R\times T_g))$	6,7
$C_2H_3 + OH \rightarrow C_2H_2 + H_2O$	5.00×10^{-11}	6,7
$C_2H_3 + CH_2O \rightarrow C_2H_4 + CHO$	$8.07\times10^{-14}\times(T_g/298)^{2.81}\times\exp(-24530/(R\times T_g))$	6,7
$C_2H_3 + CHO \rightarrow C_2H_4 + CO$	1.50×10^{-10}	6,7
$C_2H_3 + CH_3O \rightarrow C_2H_4 + CH_2O$	4.00×10^{-11}	6,7
$C_2H_2 + OH \rightarrow C_2H + H_2O$	$5.00\times10^{-12}\times(T_g/298)^{2.0}\times\exp(-58530.0/(R\times T_g))$	6,7
$C_2H_2 + HO_2 \rightarrow CH_2CO + OH$	$1.00\times10^{-14}\times\exp(-33260/(R\times T_g))$	6,7
$C_2H + OH \rightarrow CH_2 + CO$	3.01×10^{-11}	6,7
$C_2H + OH \rightarrow C_2H_2 + O$	3.01×10^{-11}	6,7
$C_2H + HO_2 \rightarrow C_2H_2 + O_2$	3.01×10^{-11}	6,7
$C_2H + HO_2 \rightarrow C_2HO + OH$	3.01×10^{-11}	6,7
$C_2H + CHO \rightarrow C_2H_2 + CO$	1.00×10^{-10}	6,7

$C_2H + CH_3O \rightarrow C_2H_2 + CH_2O$	4.00×10^{-11}	6,7
$C_2H + CH_3O_2 \rightarrow CH_3O + C_2HO$	4.00×10^{-11}	6,7
$C_3H_8 + OH \rightarrow C_3H_7 + H_2O$	$1.44\times10^{-12}\times(T_g/298)\times\exp(-1.08\times10^3/(R\times T_g))$	6,7
$C_3H_8 + HO_2 \rightarrow C_3H_7 + H_2O_2$	$1.61\times10^{-13}\times(T_g/298)^{2.55}\times\exp(-69010/(R\times T_g))$	6,7
$C_3H_8 + CHO \rightarrow C_3H_7 + CH_2O$	$5.21\times10^{-13}\times(T_g/298)^{2.50}\times\exp(-77160/(R\times T_g))$	6,7
$C_3H_8 + CH_3O \rightarrow C_3H_7 + CH_3OH$	$7.21\times10^{-13}\times\exp(-27020/(R\times T_g))$	6,7
$C_3H_8 + CH_3O_2 \rightarrow C_3H_7 + CH_3OOH$	$1.00\times10^{-11}\times\exp(-81070/(R\times T_g))$	6,7
$C_3H_7 + CH_2O \rightarrow C_3H_8 + CHO$	$7.49\times10^{-14}\times(T_g/298)^{2.9}\times\exp(-24530/(R\times T_g))$	6,7
$C_3H_7 + CHO \rightarrow C_3H_8 + CO$	1.00×10^{-10}	6,7
$C_3H_7 + CH_3O \rightarrow C_3H_8 + CH_2O$	4.00×10^{-11}	6,7
$C_3H_7 + CH_3O_2 \rightarrow C_2H_5 + CH_2O$	5.99×10^{-11}	6,7
$H_2 + OH \rightarrow H + H_2O$	$2.06\times10^{-12}\times(T_g/298)^{1.52}\times\exp(-14470/(R\times T_g))$	6,7
$H_2 + HO_2 \rightarrow H + H_2O_2$	$5.00\times10^{-11}\times\exp(-109000/(R\times T_g))$	6,7
$H_2 + CHO \rightarrow H + CH_2O$	$2.66\times10^{-13}\times(T_g/298)^{2.0}\times\exp(-74580/(R\times T_g))$	6,7
$H_2 + CH_3O_2 \rightarrow H + CH_3OOH$	$5.00\times10^{-11}\times\exp(-109000/(R\times T_g))$	6,7
$H + CO_2 \rightarrow CO + OH$	$2.51\times10^{-10}\times\exp(-111000.0/(R\times T_g))$	6,7
$H + H_2O \rightarrow H_2 + OH$	$6.82\times10^{-12}\times(T_g/298)^{1.60}\times\exp(-80820/(R\times T_g))$	6,7
$H + OH \rightarrow H_2 + O$	$6.86\times10^{-14}\times(T_g/298)^{2.80}\times\exp(-16210/(R\times T_g))$	6,7
$H + HO_2 \rightarrow H_2 + O_2$	$1.10\times10^{-10}\times\exp(-8.90\times10^3/(R\times T_g))$	6,7
$H + HO_2 \rightarrow H_2O + O$	$5.00\times10^{-11}\times\exp(-7.20\times10^3/(R\times T_g))$	6,7
$H + HO_2 \rightarrow OH + OH$	$2.81\times10^{-10}\times\exp(-3.66\times10^3/(R\times T_g))$	6,7
$H + CH_2O \rightarrow H_2 + CHO$	$2.14\times10^{-12}\times(T_g/298)^{1.62}\times\exp(-9060/(R\times T_g))$	6,7
$H + CHO \rightarrow H_2 + CO$	5.50×10^{-10}	6,7
$H + CH_3O \rightarrow H_2 + CH_2O$	2.32×10^{-11}	6,7
$H + CH_3O \rightarrow CH_3 + OH$	9.93×10^{-12}	6,7
$H + CH_2CO \rightarrow CH_3 + CO$	1.04×10^{-13}	6,7
$H + C_2HO \rightarrow CH_2 + CO$	2.50×10^{-10}	6,7
$H + CH_3O_2 \rightarrow OH + CH_3O$	1.60×10^{-10}	6,7
$O + H_2O \rightarrow OH + OH$	$1.25\times10^{-11}\times(T_g/298)^{1.3}\times\exp(-71500/(R\times T_g))$	6,7
$O + OH \rightarrow H + O_2$	$2.41\times10^{-11}\times\exp(-2.94\times10^3/(R\times T_g))$	6,7
$O + HO_2 \rightarrow O_2 + OH$	$2.91\times10^{-11}\times\exp(1.66\times10^3/(R\times T_g))$	6,7
$O + CH_2O \rightarrow OH + CHO$	$1.78\times10^{-11}\times(T_g/298)^{0.57}\times\exp(-11560/(R\times T_g))$	6,7
$O + CHO \rightarrow CO + OH$	5.00×10^{-11}	6,7
$O + CHO \rightarrow H + CO_2$	5.00×10^{-11}	6,7

$O + CH_3O \rightarrow CH_3 + O_2$	2.20×10^{-11}	6,7
$O + CH_3O \rightarrow OH + CH_2O$	1.00×10^{-11}	6,7
$O + CH_3CHO \rightarrow OH + CH_3CO$	$8.30\times10^{-12}\times\exp(-7.50\times10^{3}/(R\times T_g))$	6,7
$O + CH_2CO \rightarrow CH_2 + CO_2$	2.29×10^{-13}	6,7
$O + CH_2CO \rightarrow CH_2O + CO$	7.88×10^{-14}	6,7
$O + CH_2CO \rightarrow CHO + CO + H$	4.33×10^{-14}	6,7
$O + CH_2CO \rightarrow CHO + CHO$	4.33×10^{-14}	6,7
$O + C_2HO \rightarrow CO + CO + H$	1.60×10^{-10}	6,7
$O + CH_3O_2 \rightarrow CH_3O + O_2$	5.99×10^{-11}	6,7
$O + CH_3OOH \rightarrow CH_3O_2 + OH$	5.63×10^{-15}	6,7
$O_2 + CHO \rightarrow CO + HO_2$	7.14×10^{-11}	6,7
$O_2 + CH_3O \rightarrow CH_2O + HO_2$	1.97×10^{-15}	6,7
$O_2 + C_2HO \rightarrow CO + CO + OH$	6.46×10^{-13}	6,7
$CO + OH \rightarrow CO_2 + H$	$5.40\times10^{-14}\times(T_g/298)^{1.50}\times\exp(2080/(R\times T_g))$	6,7
$CO + HO_2 \rightarrow CO_2 + OH$	$2.51\times10^{-10}\times\exp(-98940/(R\times T_g))$	6,7
$CO + CH_3O \rightarrow CO_2 + CH_3$	$2.61\times10^{-11}\times\exp(-49390/(R\times T_g))$	6,7
$H_2O + CHO \rightarrow CH_2O + OH$	$8.54\times10^{-13}\times(T_g/298)^{1.35}\times\exp(-109000/(R\times T_g))$	6,7
$H_2O + CH_3O \rightarrow CH_3OH + OH$	$1.46\times10^{-15}\times(T_g/298)^{3.80}\times\exp(-48060/(R\times T_g))$	6,7
$OH + OH \rightarrow H_2O + O$	$1.65\times10^{-12}\times(T_g/298)^{1.14}\times\exp(-0.42\times10^{3}/(R\times T_g))$	6,7
$OH + HO_2 \rightarrow O_2 + H_2O$	$4.80\times10^{-11}\times\exp(2.08\times10^{3}/(R\times T_g))$	6,7
$OH + CH_2O \rightarrow H_2O + CHO$	$4.73\times10^{-12}\times(T_g/298)^{1.18}\times\exp(1.87\times10^{3}/(R\times T_g))$	6,7
$OH + CHO \rightarrow CO + H_2O$	1.69×10^{-10}	6,7
$OH + CH_3O \rightarrow CH_2O + H_2O$	3.01×10^{-11}	6,7
$OH + CH_3CHO \rightarrow CH_3CO + H_2O$	1.49×10^{-11}	6,7
$OH + CH_2CO \rightarrow CO + CH_2OH$	1.14×10^{-11}	6,7
$OH + CH_3O_2 \rightarrow CH_3OH + O_2$	1.00×10^{-10}	6,7
$HO_2 + HO_2 \rightarrow H_2O_2 + O_2$	1.63×10^{-12}	6,7
$HO_2 + CH_2O \rightarrow CHO + H_2O_2$	$3.30\times10^{-12}\times\exp(-48810/(R\times T_g))$	6,7
$HO_2 + CHO \rightarrow OH + H + CO_2$	5.00×10^{-11}	6,7
$HO_2 + CH_3O \rightarrow CH_2O + H_2O_2$	5.00×10^{-13}	6,7
$HO_2 + CH_3O_2 \rightarrow CH_3OOH + O_2$	5.12×10^{-12}	6,7
$CH_2O + CH_3O \rightarrow CH_3OH + CHO$	$1.69\times10^{-13}\times\exp(-12470/(R\times T_g))$	6,7
$CH_2O + CH_3O_2 \rightarrow CHO + CH_3OOH$	$3.30\times10^{-12}\times\exp(-48810/(R\times T_g))$	6,7
$CHO + CHO \rightarrow CH_2O + CO$	5.00×10^{-11}	6,7

$CHO + CH_3O \rightarrow CH_3OH + CO$	1.50×10^{-10}	6,7
$CHO + CH_3O_2 \rightarrow CH_3O + H + CO_2$	5.00×10^{-11}	6,7
$CH_3O + CH_3O \rightarrow CH_2O + CH_3OH$	1.00×10^{-10}	6,7
$CH_3O + CH_3O_2 \rightarrow CH_2O + CH_3OOH$	5.00×10^{-13}	6,7
$CH_3O_2 + CH_3O_2 \rightarrow CH_3OH + CH_2O + O_2$	2.19×10^{-13}	6,7
$CH_3O_2 + CH_3O_2 \rightarrow CH_3O + CH_3O + O_2$	1.29×10^{-13}	6,7
$CH_4 + CH_3CO \rightarrow CH_3CHO + CH_3$	$4.82\times10^{-14}\times(T_g/298)^{2.88}\times\exp(-89800/(R\times T_g))$	6,7
$CH_4 + CH_2OH \rightarrow CH_3OH + CH_3$	$1.68\times10^{-15}\times(T_g/298)^{3.10}\times\exp(-67930/(R\times T_g))$	6,7
$CH_3 + H_2O_2 \rightarrow CH_4 + HO_2$	$2.01\times10^{-14}\times\exp(2490/(R\times T_g))$	6,7
$CH_3 + CH_3OH \rightarrow CH_4 + CH_3O$	$1.12\times10^{-15}\times(T_g/298)^{3.10}\times\exp(-29020/(R\times T_g))$	6,7
$CH_3 + CH_3OH \rightarrow CH_4 + CH_2OH$	$4.38\times10^{-15}\times(T_g/298)^{3.20}\times\exp(-30020/(R\times T_g))$	6,7
$CH_3 + CH_2OH \rightarrow CH_4 + CH_2O$	4.00×10^{-12}	6,7
$CH_2 + H_2O_2 \rightarrow CH_3 + HO_2$	1.00×10^{-14}	6,7
$CH_2 + CH_3CO \rightarrow CH_2CO + CH_3$	3.01×10^{-11}	6,7
$CH_2 + CH_3OH \rightarrow CH_3O + CH_3$	$1.12\times10^{-15}\times(T_g/298)^{3.10}\times\exp(-29020/(R\times T_g))$	6,7
$CH_2 + CH_3OH \rightarrow CH_2OH + CH_3$	$4.38\times10^{-15}\times(T_g/298)^{3.20}\times\exp(-30020/(R\times T_g))$	6,7
$CH_2 + CH_2OH \rightarrow CH_2O + CH_3$	2.01×10^{-12}	6,7
$CH_2 + CH_2OH \rightarrow C_2H_4 + OH$	4.00×10^{-11}	6,7
$C_2H_6 + CH_3C \rightarrow CH_3CHO + C_2H_5$	$1.91\times10^{-13}\times(T_g/298)^{2.75}\times\exp(-73334/(R\times T_g))$	6,7
$C_2H_6 + CH_2OH \rightarrow CH_3OH + C_2H_5$	$8.73\times10^{-15}\times(T_g/298)^{3.00}\times\exp(-58451/(R\times T_g))$	6,7
$C_2H_5 + H_2O_2 \rightarrow C_2H_6 + HO_2$	$1.45\times10^{-14}\times\exp(-4070/(R\times T_g))$	6,7
$C_2H_5 + CH_3OH \rightarrow C_2H_6 + CH_3O$	$1.12\times10^{-15}\times(T_g/298)^{3.10}\times\exp(-37420/(R\times T_g))$	6,7
$C_2H_5 + CH_3OH \rightarrow C_2H_6 + CH_2OH$	$4.38\times10^{-15}\times(T_g/298)^{3.20}\times\exp(-38330/(R\times T_g))$	6,7
$C_2H_5 + CH_2OH \rightarrow C_2H_6 + CH_2O$	4.00×10^{-12}	6,7
$C_2H_5 + CH_2OH \rightarrow CH_3OH + C_2H_4$	4.00×10^{-12}	6,7
$C_2H_3 + H_2O_2 \rightarrow C_2H_4 + HO_2$	$2.01\times10^{-14}\times\exp(2490/(R\times T_g))$	6,7
$C_2H_3 + CH_3OH \rightarrow C_2H_4 + CH_3O$	$1.12\times10^{-15}\times(T_g/298)^{3.10}\times\exp(-29020/(R\times T_g))$	6,7
$C_2H_3 + CH_3OH \rightarrow C_2H_4 + CH_2OH$	$4.38\times10^{-15}\times(T_g/298)^{3.20}\times\exp(-30020/(R\times T_g))$	6,7
$C_2H_3 + CH_2OH \rightarrow C_2H_4 + CH_2O$	5.00×10^{-11}	6,7
$C_2H_3 + CH_2OH \rightarrow C_3H_5 + OH$	2.01×10^{-11}	6,7
$C_2H_2 + CH_2OH \rightarrow C_2H_3 + CH_2O$	$1.20\times10^{-12}\times\exp(-37660/(R\times T_g))$	6,7
$C_2H + CH_3OH \rightarrow C_2H_2 + CH_3O$	2.01×10^{-12}	6,7
$C_2H + CH_3OH \rightarrow C_2H_2 + CH_2OH$	1.00×10^{-11}	6,7
$C_2H + CH_2OH \rightarrow C_2H_2 + CH_2O$	5.99×10^{-11}	6,7

$C_3H_8 + CH_3CO \rightarrow CH_3CHO + C_3H_7$	$1.89\times10^{-13}\times(T_g/298)^{2.60}\times\exp(-73916/(R\times T_g))$	6,7
$C_3H_8 + CH_2OH \rightarrow CH_3OH + C_3H_7$	$6.56\times10^{-15}\times(T_g/298)^{2.95}\times\exp(-58451/(R\times T_g))$	6,7
$C_3H_7 + OH \rightarrow C_3H_6 + H_2O$	4.00×10^{-11}	6,7
$C_3H_7 + H_2O_2 \rightarrow C_3H_8 + HO_2$	$5.15\times10^{-15}\times(T_g/298)^{2.11}\times\exp(-10730/(R\times T_g))$	6,7
$C_3H_7 + CH_3OH \rightarrow C_3H_8 + CH_3O$	$1.12\times10^{-15}\times(T_g/298)^{3.10}\times\exp(-37420/(R\times T_g))$	6,7
$C_3H_7 + CH_3OH \rightarrow C_3H_8 + CH_2OH$	$3.90\times10^{-15}\times(T_g/298)^{3.17}\times\exp(-38330/(R\times T_g))$	6,7
$C_3H_7 + CH_2OH \rightarrow C_3H_8 + CH_2O$	1.60×10^{-12}	6,7
$C_3H_7 + CH_2OH \rightarrow C_3H_6 + CH_3OH$	8.00×10^{-13}	6,7
$C_3H_6 + O \rightarrow C_3H_5 + OH$	$1.56\times10^{-11}\times(T_g/298)^{0.70}\times\exp(-24610/(R\times T_g))$	6,7
$C_3H_6 + OH \rightarrow C_3H_5 + H_2O$	$4.60\times10^{-13}\times(T_g/298)^{2.0}\times\exp(1250/(R\times T_g))$	6,7
$C_3H_6 + HO_2 \rightarrow C_3H_5 + H_2O_2$	$4.33\times10^{-14}\times(T_g/298)^{2.6}\times\exp(-58200/(R\times T_g))$	6,7
$C_3H_6 + CHO \rightarrow C_3H_5 + CH_2O$	$9.05\times10^{-13}\times(T_g/298)^{1.9}\times\exp(-71170/(R\times T_g))$	6,7
$C_3H_6 + CH_3O \rightarrow C_3H_5 + CH_3OH$	$2.97\times10^{-15}\times(T_g/298)^{2.95}\times\exp(-50140/(R\times T_g))$	6,7
$C_3H_6 + CH_3O_2 \rightarrow C_3H_5 + CH_3OOH$	$3.30\times10^{-12}\times\exp(-71340/(R\times T_g))$	6,7
$C_3H_6 + CH_3CO \rightarrow C_3H_5 + CH_3CHO$	$7.82\times10^{-13}\times(T_g/298)^{2.00}\times\exp(-67930/(R\times T_g))$	6,7
$C_3H_6 + CH_2OH \rightarrow C_3H_5 + CH_3OH$	$1.99\times10^{-15}\times(T_g/298)^{2.95}\times\exp(-50140/(R\times T_g))$	6,7
$C_3H_5 + HO_2 \rightarrow C_3H_6 + O_2$	4.40×10^{-12}	6,7
$C_3H_5 + H_2O_2 \rightarrow C_3H_6 + HO_2$	$7.67\times10^{-14}\times(T_g/298)^{2.05}\times\exp(-56790/(R\times T_g))$	6,7
$C_3H_5 + CH_2O \rightarrow C_3H_6 + CHO$	$1.05\times10^{-11}\times(T_g/298)^{1.9}\times\exp(-76080/(R\times T_g))$	6,7
$C_3H_5 + CHO \rightarrow C_3H_6 + CO$	1.00×10^{-10}	6,7
$C_3H_5 + CH_3O \rightarrow C_3H_6 + CH_2O$	5.00×10^{-11}	6,7
$C_3H_5 + CH_3OH \rightarrow C_3H_6 + CH_2OH$	$4.33\times10^{-14}\times(T_g/298)^{2.9}\times\exp(-85640/(R\times T_g))$	6,7
$C_3H_5 + CH_2OH \rightarrow C_3H_6 + CH_2O$	3.01×10^{-11}	6,7
$H_2 + CH_3CO \rightarrow CH_3CHO + H$	$2.18\times10^{-13}\times(T_g/298)^{1.82}\times\exp(-73670/(R\times T_g))$	6,7
$H_2 + CH_2OH \rightarrow CH_3OH + H$	$9.96\times10^{-14}\times(T_g/298)^{2.0}\times\exp(-55870/(R\times T_g))$	6,7
$H + H_2O_2 \rightarrow H_2O + OH$	$1.69\times10^{-11}\times\exp(-14970/(R\times T_g))$	6,7
$H + H_2O_2 \rightarrow H_2 + HO_2$	$2.81\times10^{-12}\times\exp(-15710/(R\times T_g))$	6,7
$H + CH_3OH \rightarrow CH_2OH + H_2$	$2.42\times10^{-12}\times(T_g/298)^{2.0}\times\exp(-18870/(R\times T_g))$	6,7
$H + CH_3OH \rightarrow CH_3O + H_2$	3.18×10^{-16}	6,7
$H + CH_2OH \rightarrow CH_2O + H_2$	1.00×10^{-11}	6,7
$H + CH_2OH \rightarrow CH_3 + OH$	1.60×10^{-10}	6,7
$H + CH_3OOH \rightarrow H_2O + CH_3O$	5.88×10^{-15}	6,7
$H + CH_3OOH \rightarrow H_2 + CH_3O_2$	7.11×10^{-15}	6,7
$O + H_2O_2 \rightarrow HO_2 + OH$	$1.42\times10^{-12}\times(T_g/298)^{2.0}\times\exp(-16.63\times10^3/(R\times T_g))$	6,7

$O + H_2O_2 \rightarrow O_2 + H_2O$	8.91×10^{-16}	6,7
$O + CH_3CO \rightarrow OH + CH_2CO$	8.75×10^{-11}	6,7
$O + CH_3CO \rightarrow CO_2 + CH_3$	2.63×10^{-10}	6,7
$O + CH_3OH \rightarrow OH + CH_2OH$	$5.71\times10^{-11}\times\exp(-22.86\times10^{3}/(R\times T_g))$	6,7
$O + CH_3OH \rightarrow OH + CH_3O$	$1.66\times10^{-11}\times\exp(-19.62\times10^{3}/(R\times T_g))$	6,7
$O + CH_2OH \rightarrow CH_2O + OH$	7.00×10^{-11}	6,7
$OH + H_2O_2 \rightarrow HO_2 + H_2O$	$1.30\times10^{-11}\times\exp(-5.57\times10^{3}/(R\times T_g))$	6,7
$OH + CH_3CO \rightarrow CH_2CO + H_2O$	2.01×10^{-11}	6,7
$OH + CH_3CO \rightarrow CH_3 + CO + OH$	5.00×10^{-11}	6,7
$OH + CH_3OH \rightarrow H_2O + CH_2OH$	1.06×10^{-12}	6,7
$OH + CH_3OH \rightarrow H_2O + CH_3O$	$1.66\times10^{-11}\times\exp(-7.10\times10^{3}/(R\times T_g))$	6,7
$OH + CH_2OH \rightarrow CH_2O + H_2O$	4.00×10^{-11}	6,7
$OH + CH_3OOH \rightarrow H_2O + CH_3O_2$	$1.79\times10^{-12}\times\exp(1.83\times10^{3}/(R\times T_g))$	6,7
$HO_2 + CH_3CO \rightarrow CH_3 + CO_2 + OH$	5.00×10^{-11}	6,7
$HO_2 + CH_3OH \rightarrow CH_2OH + H_2O_2$	$1.60\times10^{-13}\times\exp(-52630/(R\times T_g))$	6,7
$HO_2 + CH_2OH \rightarrow CH_2O + H_2O_2$	2.01×10^{-11}	6,7
$CH_2O + CH_3CO \rightarrow CH_3CHO + CHO$	$3.01\times10^{-13}\times\exp(-54040/(R\times T_g))$	6,7
$CH_2O + CH_2OH \rightarrow CH_3OH + CHO$	$7.72\times10^{-14}\times(T_g/298)^{2.8}\times\exp(-24530/(R\times T_g))$	6,7
$CHO + H_2O_2 \rightarrow CH_2O + HO_2$	$1.69\times10^{-13}\times\exp(-29020/(R\times T_g))$	6,7
$CHO + CH_3CO \rightarrow CH_3CHO + CO$	1.50×10^{-11}	6,7
$CHO + CH_3OH \rightarrow CH_2O + CH_2OH$	$2.41\times10^{-13}\times(T_g/298)^{2.9}\times\exp(-54880/(R\times T_g))$	6,7
$CHO + CH_2OH \rightarrow CH_2O + CH_2O$	3.01×10^{-10}	6,7
$CHO + CH_2OH \rightarrow CH_3OH + CO$	2.01×10^{-10}	6,7
$CH_3O + CH_3CO \rightarrow CH_3OH + CH_2CO$	1.00×10^{-11}	6,7
$CH_3O + CH_3OH \rightarrow CH_3OH + CH_2OH$	$5.00\times10^{-13}\times\exp(-17040/(R\times T_g))$	6,7
$CH_3O + CH_2OH \rightarrow CH_2O + CH_3OH$	4.00×10^{-11}	6,7
$CH_3O_2 + H_2O_2 \rightarrow CH_3OOH + HO_2$	$4.00\times10^{-12}\times\exp(-41570/(R\times T_g))$	6,7
$CH_3O_2 + CH_3CO \rightarrow CH_3 + CO_2 + CH_3O$	4.00×10^{-11}	6,7
$CH_3O_2 + CH_3OH \rightarrow CH_2OH + CH_3OOH$	$3.01\times10^{-12}\times\exp(-57370/(R\times T_g))$	6,7
$CH_3O_2 + CH_2OH \rightarrow CH_3O + OH + CH_2O$	2.00×10^{-11}	6,7
$H_2O_2 + CH_3CO \rightarrow CH_3CHO + HO_2$	$3.01\times10^{-13}\times\exp(-34420/(R\times T_g))$	6,7
$H_2O_2 + CH_2OH \rightarrow CH_3OH + HO_2$	$5.00\times10^{-15}\times\exp(-10810/(R\times T_g))$	6,7
$CH_3CO + CH_3OH \rightarrow CH_3CHO + CH_2OH$	$2.13\times10^{-13}\times(T_g/298)^{3.00}\times\exp(-51630/(R\times T_g))$	6,7
$CH_3OH + CH_2OH \rightarrow CH_3OH + CH_3O$	$1.30\times10^{-14}\times\exp(-50470/(R\times T_g))$	6,7

$CH_2OH + CH_2OH \rightarrow CH_2O + CH_3OH$	8.00×10^{-12}	6,7
$CH_2 + CH_2 \rightarrow C_2H_4$	1.70×10^{-12}	6,7
$C_2H_6 + H \rightarrow CH_4 + CH_3$	$8.97\times10^{-20}\times\exp(-48.64\times10^3/(R\times T_g))$	6,7
$O + H_2O \rightarrow HO_2 + H$	$4.48\times10^{-12}\times(T_g/298)^{0.97}\times\exp(-287.0\times10^3/(R\times T_g))$	6,7
$O + H_2O \rightarrow H_2 + O_2$	$4.48\times10^{-12}\times(T_g/298)^{0.97}\times\exp(-287.0\times10^3/(R\times T_g))$	6,7
$O + CH_2 \rightarrow CHO + H$	5.01×10^{-11}	6,7
$CH_3 + O \rightarrow CH_3O$	$7.51\times10^{-14}\times(T_g/298)^{-2.12}\times\exp(-2.61\times10^3/(R\times T_g))$	6,7
$CH + H_2O \rightarrow CH_2O + H$	$2.82\times10^{-11}\times(T_g/298)^{-1.22}\times\exp(-0.10\times10^3/(R\times T_g))$	6,7
$C_2H_2 + H_2 \rightarrow C_2H_4$	$5.00\times10^{-13}\times\exp(-163.0\times10^3/(R\times T_g))$	6,7
$C_2H_2 + CO \rightarrow C_2H + CHO$	$8.00\times10^{-10}\times\exp(-446.0\times10^3/(R\times T_g))$	6,7
$C_2H_2 + OH \rightarrow CO + CH_3$	$9.13\times10^{-11}\times\exp(-57.29\times10^3/(R\times T_g))$	6,7
$CO + CH_3 \rightarrow C_2H_2 + OH$	$6.31\times10^{-11}\times\exp(-253\times10^3/(R\times T_g))$	6,7
$C_2H_2 + H_2 \rightarrow C_2H_3 + H$	$4.00\times10^{-12}\times\exp(-272.0\times10^3/(R\times T_g))$	6,7
$C_2H_4 + H_2 \rightarrow C_2H_5 + H$	$1.69\times10^{-11}\times\exp(-285.0\times10^3/(R\times T_g))$	6,7
$H_2 + O_2 \rightarrow HO_2 + H$	$2.41\times10^{-10}\times\exp(-237.0\times10^3/(R\times T_g))$	6,7
$H_2 + CH_3O \rightarrow CH_3OH + H$	$1.66\times10^{-15}\times(T_g/298)^{4.0}\times\exp(-20.54\times10^3/(R\times T_g))$	6,7
$OH + O_2 \rightarrow HO_2 + O$	$3.70\times10^{-11}\times\exp(-220000.0/(R\times T_g))$	6,7
$C_2H_5 + OH \rightarrow C_2H_6 + O$	$9.85\times10^{-19}\times(T_g/298)^{8.8}\times\exp(-2.08\times10^3/(R\times T_g))$	6,7
$C_2H + H_2O \rightarrow C_2H_2 + OH$	$7.74\times10^{-14}\times(T_g/298)^{3.05}\times\exp(-3.13\times10^3/(R\times T_g))$	6,7
$OH + OH \rightarrow HO_2 + H$	$3.32\times10^{-12}\times(T_g/298)^{0.51}\times\exp(-211\times10^3/(R\times T_g))$	6,7
$H_2O + O_2 \rightarrow HO_2 + OH$	$7.72\times10^{-12}\times\exp(-310000.0/(R\times T_g))$	6,7
$HO_2 + H_2O \rightarrow OH + H_2O_2$	$4.65\times10^{-11}\times\exp(-137.0\times10^3/(R\times T_g))$	6,7
$CH_2OH + H_2O \rightarrow CH_3OH + OH$	$4.12\times10^{-14}\times(T_g/298)^{3.0}\times\exp(-86.80\times10^3/(R\times T_g))$	6,7
$C_2H_6 \rightarrow C_2H_5 + H$	$8.11\times10^{17}\times(T_g/298)^{-1.23}\times\exp(-427.0\times10^3/(R\times T_g))$	6,7
$CH_3 + CH_3 \rightarrow CH_4 + CH_2$	$7.14\times10^{-12}\times\exp(-41.99\times10^3/(R\times T_g))$	6,7
$C_2H_4 + C_3H_6 \rightarrow C_3H_5 + C_2H_5$	$9.60\times10^{-11}\times\exp(-216.0\times10^3/(R\times T_g))$	6,7
$C_2H_4 + C_2H_2 \rightarrow C_2H_3 + C_2H_3$	$4.00\times10^{-11}\times\exp(-286.0\times10^3/(R\times T_g))$	6,7
$C_2H_2 + C_2H_2 \rightarrow C_2H + C_2H_3$	$1.60\times10^{-11}\times\exp(-353.0\times10^3/(R\times T_g))$	6,7
$C_2H_4 + C_3H_6 \rightarrow C_2H_3 + C_3H_7$	$1.00\times10^{-10}\times\exp(-316.0\times10^3/(R\times T_g))$	6,7
$C_3H_6 + C_2H_2 \rightarrow C_2H_3 + C_3H_5$	$6.71\times10^{-11}\times\exp(-196.0\times10^3/(R\times T_g))$	6,7
$C_3H_6 + C_3H_6 \rightarrow C_3H_7 + C_3H_5$	$4.20\times10^{-10}\times\exp(-231.0\times10^3/(R\times T_g))$	6,7
$CH_4 + O_2 \rightarrow CH_3 + HO_2$	$6.59\times10^{-11}\times\exp(-238000.0/(R\times T_g))$	6,7
$C_2H_6 + O_2 \rightarrow C_2H_5 + HO_2$	$1.00\times10^{-10}\times\exp(-217000.0/(R\times T_g))$	6,7
$CO + C_2H_4 \rightarrow CHO + C_2H_3$	$2.51\times10^{-10}\times\exp(-379000.0/(R\times T_g))$	6,7

$C_2H_2 + O_2 \rightarrow C_2H + HO_2$	$2.01\times10^{-11}\times\exp(-312000.0/(R\times T_g))$	6,7
$CH_3 + O_2 \rightarrow CH_3O + O$	$1.25\times10^{-11}\times\exp(-118000.0/(R\times T_g))$	6,7
$H_2O_2 + O_2 \rightarrow HO_2 + HO_2$	$9.00\times10^{-11}\times\exp(-166000.0/(R\times T_g))$	6,7
$CH_3CHO + C_2H_5 \rightarrow C_2H_6 + CH_3CO$	$2.09\times10^{-12}\times\exp(-35.59\times10^{3}/(R\times T_g))$	6,7
$CH_3CHO + C_3H_5 \rightarrow C_3H_6 + CH_3CO$	$6.31\times10^{-13}\times\exp(-30.18\times10^{3}/(R\times T_g))$	6,7
$C_3H_6 + O_2 \rightarrow C_3H_5 + HO_2$	$9.00\times10^{-11}\times\exp(-166000.0/(R\times T_g))$	6,7
$CH_2O + HO_2 \rightarrow CH_2OH + O_2$	$5.63\times10^{-12}\times\exp(-79.99\times10^{3}/(R\times T_g))$	6,7
$CH_3CHO + HO_2 \rightarrow H_2O_2 + CH_3CO$	$5.00\times10^{-12}\times\exp(-49.89\times10^{3}/(R\times T_g))$	6,7
$CH_3CHO + CH_2OH \rightarrow CH_3CO + CH_3OH$	8.30×10^{-15}	6,7
$C_2H_2 + HO_2 \rightarrow C_2H_3 + O_2$	$5.00\times10^{-14}\times(T_g/298)^{1.61}\times\exp(-59.28\times10^{3}/(R\times T_g))$	6,7
$C_2H_3 + O_2 \rightarrow C_2H_2 + HO_2$	$2.14\times10^{-14}\times(T_g/298)^{1.61}\times\exp(1.60\times10^{3}/(R\times T_g))$	6,7
$C_2H_4 + C_2H_4 \rightarrow C_2H_5 + C_2H_3$	$8.00\times10^{-10}\times\exp(-299.0\times10^{3}/(R\times T_g))$	6,7
$CH_4 + CH_3 \rightarrow H + C_2H_6$	$1.33\times10^{-10}\times\exp(-167000.0/(R\times T_g))$	6,7
$C_2H_4 + CH_3 \rightarrow C_3H_7$	$4.00\times10^{-14}\times(T_g/298)^{2.48}\times\exp(-25.65\times10^{3}/(R\times T_g))$	6,7
$C_3H_5 \rightarrow C_2H_2 + CH_3$	$1.26\times10^{13}\times\exp(-140\times10^{3}/(R\times T_g))$	6,7
$CH + CH_2 \rightarrow C_2H_2 + H$	6.64×10^{-11}	6,7
$CH_2 + CH_2 \rightarrow C_2H_2 + H_2$	$2.66\times10^{-9}\times\exp(-11944.0/(1.987\times T_g))$	6,7
$C + CH_3 \rightarrow H + C_2H_2$	8.30×10^{-11}	6,7
$CH + C_2H_3 \rightarrow CH_2 + C_2H_2$	8.30×10^{-11}	6,7
$C_2H_2 + CH \rightarrow C_2H + CH_2$	$3.50\times10^{-10}\times\exp(172.0/(1.987\times T_g))$	6,7
$CO_2 + O \rightarrow CO + O_2$	$7.95\times10^{-12}\times\exp(-1.81612\times10^{4})/T_g)$	6,7
$O_2 + CO \rightarrow CO_2 + O$	$3.99\times10^{-14}\times\exp(-1.527467\times10^{4}/T_g)$	6,7
$O_2 + C \rightarrow CO + O$	$1.99\times10^{-10}\times\exp(-2.01\times10^{3}/T_g)$	6,7
$HCOOH \rightarrow CO_2 + H_2$	$4.46\times10^{13}\times\exp(-2.86\times10^{5}/(R\times T_g))$	6,7
$HCOOH + OH \rightarrow COOH + H_2O$	$9.85\times10^{-13}\times\exp(-8614.0/(R\times T_g))$	6,7
$CO + H_2O_2 \rightarrow COOH + OH$	$9.60\times10^{-14}\times(T_g/298)^{2.09}\times\exp(-2.28\times10^{4}/(R\times T_g))$	6,7
$COOH \rightarrow CO + OH$	$29.85\times(T_g/298)^{0.13}\times\exp(-1.53\times10^{5}/(R\times T_g))$	6,7
$COOH \rightarrow CO_2 + H$	$125.0\times(T_g/298)^{0.41}\times\exp(-1.48\times10^{5}/(R\times T_g))$	6,7
$COOH + O \rightarrow CO_2 + OH$	1.44×10^{-11}	6,7
$COOH + OH \rightarrow CO_2 + H_2O$	1.03×10^{-11}	6,7
$HCOO \rightarrow CO + OH$	$1.21\times10^{14}\times(T_g/298)^{0.53}\times\exp(-1.42\times10^{5}/(R\times T_g))$	6,7
$HCOO \rightarrow CO_2 + H$	$1.00\times10^{13}\times(T_g/298)^{0.31}\times\exp(-1.38\times10^{5}/(R\times T_g))$	6,7
$C_2H_4 + O \rightarrow C_2H_3 + OH$	$1.33\times10^{-12}\times(T_g/298)^{1.91}\times\exp(-1.56\times10^{4}/(R\times T_g))$	6,7
$C_2H_5O + C_2H_6 \rightarrow C_2H_5OH + C_2H_5$	$4.00\times10^{-13}\times\exp(-29680/(R\times T_g))$	6,7

$C_2H_5O + CHO \rightarrow C_2H_5OH + CO$	1.50×10^{-10}	6,7
$CH_3 + C_2H_5 \rightarrow C_3H_8$	$3.47\times10^{-11}\times(T_g/298)^{-0.34}\times\exp(2150.0/(R\times T_g))$	6,7
$CH_3 + H \rightarrow CH_4$	3.50×10^{-10}	6,7
$C_2H_5O \rightarrow CH_2O + CH_3$	$1.00\times10^{15}\times\exp(-9.06\times10^4/(R\times T_g))$	6,7
$H + H_2 \rightarrow H + H + H$	$\exp(@B+@C\times T_g+@D\times T_g^2+(@E)\times T_g^3+@F\times\mathrm{Log}(T_g)+@G\times\exp(T_g/11600))$	6,7

@B = -496.794, @C = -0.0237, @D = 4.729×10^{-7}, @E = -4.327×10^{-11}, @F = 47.387, @G = 113.761

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