A Chemical Kinetics Network for Lightning and Life in Planetary Atmospheres

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ABSTRACT

There are many open questions about prebiotic chemistry in both planetary and exoplanetary environments. The increasing number of known exoplanets and other ultra-cool, substellar objects has propelled the desire to detect life and prebiotic chemistry outside the solar system. We present an ion-neutral chemical network constructed from scratch, STAND2015, that treats hydrogen, nitrogen, carbon and oxygen chemistry accurately within a temperature range between 100 K and 30000 K. Formation pathways for glycine and other organic molecules are included. The network is complete up to H6C2N2O3. STAND2015 is successfully tested against atmospheric chemistry models for HD209458b, Jupiter and the present-day Earth using a simple 1D photochemistry/diffusion code. Our results for the early Earth agree with those of Kasting (1993) for CO₂, H₂, CO and O₂, but do not agree for water and atomic oxygen. We use the network to simulate an experiment where varied chemical initial conditions are irradiated by UV light. The result from our simulation is that more glycine is produced when more ammonia and methane is present. Very little glycine is produced in the absence of any molecular nitrogen and oxygen. This suggests that production of glycine is inhibited if a gas is too strongly reducing. Possible applications and limitations of the chemical kinetics network are also discussed.

Subject headings: astrobiology — atmospheric effects — molecular processes — planetary systems

1. Introduction

The potential connection between a focused source of energy and life was first made apparent in the Miller-Urey experiment (Miller 1953), set to test a hypothesis proposed by Haldane (1928). In this experiment, a gas composed of water vapor, ammonia, methane and molecular hydrogen was circulated past an electric discharge. After a week's time, various biologically relevant chemicals had developed, including glycine and alanine, identified with a paper chromatrogram. A followup study of Miller's samples, carried out approximately fifty years later, discovered a much richer variety of prebiotic compounds than originally thought (Johnson et al. 2008). Since then, numerous related experiments have been carried out under a variety of conditions (see Miller & Urey 1959; Cleaves et al. 2008, and references therein).

The input energy source and the initial chemistry have been varied across these different experiments. An energy source may have been important for the production of prebiotic species on Earth, because the pathways to formation have considerable activation barriers, often on the order of 0.1-1 eV. Patel et al. (2015) generated prebiotic species by exposing HCN and H₂S to ultraviolet light. The experimental results from Powner et al. (2009) suggest that the aqueous synthesis of amino acids, nucleobases and ribose is predisposed, starting from glyceraldehyde and glycoaldehyde, which they suggest would most likely form through heating and UV irradiation. Shock synthesis of amino acids due to the atmospheric entry of cometary meteors and micrometeorites or thunder is also sufficient to overcome these barriers and produce amino acids (Bar-Nun et al. 1970).

The initial chemical conditions are naturally significant to the formation of prebiotic chemistry.

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Of course, in an environment where hydrogen or carbon were lacking, there would be no complex hydrocarbons. Nitrogen and phosphorus are also essential to the origins of terrestrial life, although some scientists, such as Benner et al. (2004), have speculated that life could occur under very different chemistries; presently, we lack the ability to explore this possibility. The initial chemical composition also has an effect on the production of prebiotic chemical species. For example, hydrogen can be bound in a reducing species, CH₄, in an oxidizing species, H₂SO₄, or into the neutral species of water (H₂O). Both Schlesinger & Miller (1983) and Miyakawa et al. (2002) have found that performing a Miller-Urev like experiment in an oxidizing environment produces only trace amounts of prebiotic materials, whereas performing the experiment in a reducing environment produces a great number of prebiotic materials.

The atmosphere of Earth in its present state is oxidizing ($\approx 21\% \text{ O}_2$, 78 % N₂). The atmosphere of the Earth during its first billion years (first 1 Gyr) would have had a very different composition, probably oxidizing or at least only weakly reducing (Kasting 1993), although Tian et al. (2005) suggest that the Earth's atmosphere was once highly reducing. Even if the Earth never possessed a strongly reducing atmosphere, other planets and moons are known to have both reducing atmospheres and active lighting and UV photochemistry, Jupiter for example. Extrasolar planets may not simply have diverse compositions, but also widely varied gas-phase C/O ratios, either intrinsically at formation, as may be the case with Wasp-12b, XO-1b, CoRoT-2b (Madhusudhan et al. 2011; Moses et al. 2013), and possibly the interior of 55 Cancri e (Madhusudhan et al. 2012, but see also Nissen 2013); or alternatively due to oxygen depletion into the cloud particles (Bilger et al. 2013; Helling et al. 2014). The question of the C/O ratio is not a settled matter (Benneke 2015).

These diverse planetary and exoplanetary environments provide unique "laboratories" within which to explore prebiotic chemistry. There are many potential drivers for prebiotic chemistry in planets and exoplanets, from the steep thermal gradients in hot Jupiters and close-in Super-Earths to the thermal production of organics and complex hydrocarbons in Saturn's storms (Moses 2015) and photochemical production of complex

organics in Titan (Yung et al. 1984; Loison et al. 2015). There is some evidence that cosmic rays drive the formation of hydrogen cyanide in Neptune (Lellouch et al. 1994). Molina et al. (1999) have proposed pathways to formation of a rich variety of nitriles via cosmic rays in Titan's atmosphere.

As mentioned above, electric discharges may also be an important source of energy driving the production of prebiotic species, and are ubiquitous throughout the gas giants. Discharges in the form of lightning are known to occur within our solar system, on Earth, Jupiter (Little et al. 1999), Saturn (Dyudina et al. 2007), Uranus (Zarka & Pedersen 1986), and Neptune (Gurnett et al. 1990). There are some indications of lightning discharges on Venus (Taylor et al. 1979), and possibly also in Titan's nitrogen chemistry (Borucki et al. 1984), although these traces are still tentative. Lightning is hypothesized to occur on exoplanets (Aplin 2013; Helling et al. 2013) and brown dwarfs (Helling et al. 2013; Bailey et al. 2014). Simulated plasma discharges initiated within Jupiter-like gas compositions suggest that lightning on Jupiter may produce a significant amount of trace gases (Borucki et al. The comparison between experimental 1985). rates of production of organic compounds in high-temperature plasmas to chemical equilibrium models is unsurprisingly poor (Scattergood et al. 1989), and indicates that a chemical kinetics approach will be important in explaining the results of these experiments, Chemical kinetics seems to be necessary for exploring any of these pathways to the formation of prebiotic species.

Chemical kinetics models have been applied to planetary and exoplanetary atmospheric conditions in such a diverse range that it is impractical to provide complete references, so a brief summary of the work will instead be provided. Photochemical models of the modern Earth have been applied in the context of 1D models (Owens et al. 1985), up to fully coupled 3D general circulation models (Roble & Ridley 1994), and even within a flexible modular framework that can be included as a module within other codes (Sander et al. 2005). The Earth's atmosphere during its first billion years has been extensively modeled (Kasting 1993; Chemical kinetics models have Zahnle 1986). been applied also to Jupiter's atmosphere, from

the deep atmosphere (Fegley & Lodders 1994; Visscher et al. 2010) through the stratosphere (Zahnle et al. 1995; Moses et al. 2005). The atmosphere of the moon Titan has also been analyzed using ion-neutral chemical kinetics to better explain the abundance of rich hydrocarbons in its atmosphere and its stratospheric haze (Yung et al. 1984; Keller et al. 1998; Lavvas et al. 2008a,b).

Chemical kinetics models for exoplanetary atmospheres have been typically developed for hot Jupiters, especially HD189733b and HD209458b (Moses et al. 2011; Venot et al. 2012; Zahnle et al. 2009). Almost all of the models for hot Jupiters have been applied only in two dimensions, and so have not taken a more complete account of the atmospheric dynamics, instead relying on a parameterization of vertical mixing using the eddy diffusion coefficient, K_{zz} [cm² s⁻¹] (see Lee et al. 2015, their Sec. 4.2). Agúndez et al. (2014) have taken on the ambitious task of coupling a chemical kinetics model to 2D dynamics for both HD189733b and HD209458b. Ion-neutral models have been applied to exoplanets, taking account of photochemistry (Lavvas et al. 2014), and additionally of cosmic ray ionization (Walsh & Millar 2011; Rimmer et al. 2014). Chemical kinetics models have also been applied to the extrasolar super-earths (Hu et al. 2012; Hu et al. 2013; Hu & Seager 2014), and have been used to explore possible biosignatures on rocky planets (Seager et al. 2013a,b). There has also been some recent investigation into chemistry on helium dominated exoplanets (Hu et al. 2015).

Lightning chemistry has been explored with some basic chemical kinetics models, e.g. within Earth's mesosphere (Luque & Ebert 2009 and Parra-Rojas et al. 2013) and Saturn's lower ionosphere (Dubrovin et al. 2014). Dubrovin et al. (2014) present interesting results for Saturn's lower ionosphere, predicting that TLE's within this region would produce mostly H_3^+ , what they identify as the primary positive charge carrier during the duration of the TLE and for sometime after. This would mimic the effect of cosmic ray ionization. Parra-Rojas et al. (2013) presented similar results involving terrestrial nitrogen chemistry. The products of discharge chemistry in the upper part of both hydrogen-rich and nitrogen-rich atmospheres seem to be similar to the products of cosmic ray chemistry in these same atmospheres.

There are many open questions about prebiotic chemistry in diverse planetary and exoplanetary environments, as well as in the lab. In this paper, we present a candidate network for exploring UV photochemistry, cosmic ray chemistry and lightning-driven chemistry, constructed from scratch. We will explore mostly the photochemistry and thermochemistry within this paper, leaving the exploration of lightning-driven chemistry and cosmic ray chemistry to future work.

The largest task in developing this network has been the collation of a full set of chemical reactions that treat both reducing and oxidizing chemistries at temperatures ranging from 100 K through 30000 K (the approximate peak temperature of lightning, see Orville 1968; Price et al. 1997) and the selection of rate constants when more than one is published. Since one interest is the investigation of the formation rate of prebiotic species in diverse environments, the network is made extensive enough to include the simplest amino acid, glycine. In this paper, we present this chemical network (STAND2015), and test in a diversity of environments. For these tests, we developed a simple 1D photochemistry/diffusion code (Argo). Argo was developed based on Nahoon (Wakelam et al. 2012) by including wavelengthdependent photochemistry, cosmic ray transport, water condensation and chemical mixing.

The Stand2015 network is presented in Section 2. We compare the predictions of our network using a simplified 1D photochemistry/diffusion code called Argo (Section 3). The model and network are then combined and tested against other model results for HD209458b and the early Earth, and compared to observation for Jupiter and the present-day Earth in Section 4. Finally, in Section 5 we simulate a Miller-Urey type experiment and explore the formation of glycine under various chemical conditions. Section 6 contains a short discussion of the results and possible future applications of this model.

2. The Chemical Network

The STAND2015 Atmospheric Chemical Network is an H/C/N/O network with reactions involving He, Na, Mg, Si, Cl, Ar, K, Ti and Fe, developed from scratch. It contains all known reactions for species of up to 6 hydrogen, 2 carbon, 2

nitrogen and 3 oxygen atoms, for which a rate constant has been published, as well as a less complete network involving species with 3+ carbon atoms, 3 nitrogen atoms and/or 4 oxygen atoms. A chemical network is effectively a list of chemical reactions and reaction rate constants. Rate constants are used to calculate the rates of production and loss of a particular molecular or ionic species, P_i $[\text{cm}^{-3} \text{ s}^{-1}]$ and L_i $[\text{cm}^{-3} \text{ s}^{-1}]$ respectively, and i is enumerated over the list of species. Rate constants are of zeroth order (e.g., source terms, S_i [cm⁻³] s^{-1}), first order (involving interactions with particles not accounted in the network, such as photons or cosmic rays, k_1 [s⁻¹]), second order (collisions between particle i and other particles within the network, k_2 [cm³ s⁻¹]), or third order (collisions between particle i and other particles, as well as a third body, denoted here as k_3 [cm⁶ s⁻¹]). The rates of production and loss for a given species, i, in terms of rate constants, are generally:

$$P_i = S_i + \sum k_1 n_j + \sum k_2 n_j n_k + \sum k_3 n_{gas} n_j n_k,$$
(1)

$$L_i = \sum k_1 n_i + \sum k_2 n_j n_i + \sum k_3 n_{gas} n_j n_i.$$
(2)

Summation is over all the relevant reactions, some involving species j and/or k, that result in the production (Eq. (1)) or loss (Eq. (2)) of species i. The symbol n_i [cm⁻³] denotes the number density of species i and $n_{\rm gas}$ [cm⁻³] denotes the total gas number density.

The reaction rate constants have been assembled from various databases. With only a couple hundred exceptions, the rate constants for 2-body and 3-body neutral reactions have been assembled from the NIST Chemical Kinetics Database (Manion et al. 2013). Virtually all of the ion-neutral reactions were taken from Ikezoe et al. (1987). Several rate constants that we have used, relevant for terrestrial atmospheric chemistry, are taken from Sander et al. (2011). The KIDA database provided the rate constants for several dissociative recombination reactions (Wakelam et al. 2012). Coefficients for the cosmic ray ionization rate constant were taken from the OSU chemical network (Harada et al. 2010).

Rate constants were compared to the publicly available networks of Moses et al. (2011); Venot et al. (2012), and ion-neutral rate coeffi-

cients were checked against the KIDA database (Wakelam et al. 2012)¹, as well as the OSU 09 2010 high temperature network (Harada et al. 2010)². Some further ion-neutral reactions involving the alkali ion chemistry were appropriated from Lavvas et al. (2014). Finally, ~ 20 more reactions for suspected formation pathways for glycine have been added to the network, from Blagojevic et al. (2003); Patel et al. (2015). The full network and references are provided in Appendix A. The following subsections contain brief discussions about the different classes of reactions, their rate coefficients and whether reverse reactions have been included.

2.1. 2-Body Neutral-Neutral and Ion-Neutral Reactions

Two-body neutral-neutral and ion-neutral reactions follow the basic scheme:

$$A + B \rightarrow Y + Z$$
, and (3)

$$A^{+} + B \to Y^{+} + Z.$$
 (4)

The rate constants for these reactions are approximated by the Kooij equation (Kooij 1893):

$$k_2 = \alpha \left(\frac{T}{300 K}\right)^{\beta} e^{-\gamma/T}, \tag{5}$$

where T [K] is the gas temperature³, k_2 [cm³ s⁻¹] is the rate constant, and α [cm³ s⁻¹], β and γ are constants characterizing the reaction. All of these reactions are reversed in our network and we use the rate coefficients for the best characterized direction for each reaction, which is typically the exothermic direction. For neutral-neutral reactions, even when exothermic, there is often a sizable barrier to reaction, allowing certain elements to be locked into non-equilibrium configurations at low temperatures effectively for eternity, because the barrier to the lower energy state is too large to be overcome in the current environment.

Ion-neutral reactions do not typically have barriers in the exothermic direction, and in many cases the rate constants are altogether temperature independent, closely approximating the

¹http://kida.obs.u-bordeaux1.fr/

²http://faculty.virginia.edu/ericherb/research.html

³Surface chemistry is not considered in this paper, and the temperature of all chemical species including electrons is set equal to the gas-phase temperature.

Langevin approximation. A notable exception are charge exchange reactions,

$$A^+ + B \to B^+ + A, \tag{6}$$

which, due to the differences in energy between ionic and neutral ground states, often contains barriers on the order of a few x 100 K.

The rate constants for the forward reactions are given in Appendix A with the label '2n', reactions 577-1352. These reactions are reversed following the scheme described in Appendix B. The ionneutral reactions are also reversed, are listed in Appendix A with '2i', reactions 1353-2569.

2.2. 3-Body Neutral Reactions, Dissociation Reactions, and Radiative Association Reactions

Reactions that involve a third body occur primarily in the two forms:

$$A + M \to Y + Z + M, \tag{7}$$

$$A + B + M \to Z + M, \tag{8}$$

where M represents any third body. Decomposition reactions are well studied at high temperatures, being important for various combustion processes. Just as in Section 2.1, we choose the reactions best characterized, which in this case often involve endothermic reactions. The rate coefficients for the majority of these reactions follow the Lindemann form (Lindemann et al. 1922). In this form, we first determine the rate constants in the low-pressure $(k_0 \text{ [cm}^6 \text{ s}^{-1}])$ and high-pressure $(k_\infty \text{ [cm}^3 \text{ s}^{-1}])$ limits:

$$k_0 = \alpha_0 \left(\frac{T}{300 \, K}\right)^{\beta_0} e^{-\gamma_0/T},$$
 (9)

$$k_{\infty} = \alpha_{\infty} \left(\frac{T}{300 \, K}\right)^{\beta_{\infty}} e^{-\gamma_{\infty}/T}. \tag{10}$$

These are combined with the number density of the neutral third species, [M] [cm⁻³] to determine the reduced pressure, $p_r = k_0[\mathrm{M}]/k_{\infty}$, and this can then be utilized to set the pressure-dependent effective "two-body" rate:

$$k_2 = \frac{k_\infty p_r}{1 + p_r}. (11)$$

Sometimes this expression is multiplied by a dimensionless function F(p,T) to more accurately

approximate the transition between the low-pressure and high-pressure limits, and this provides the Troe form (Troe 1983). The coefficients for the Troe form are not explicitly given.

We favor using the rate constants for three-body combination reactions, and reversing these reaction to determine the rate of thermal decomposition. In many cases, however, the rate constants are unavailable. When we have only the rate coefficients for the decomposition reactions, we add an additional 500 K barrier to both the decomposition and three body combination rate constants. This barrier is added in order to limit runaway three body reactions that can result from reversing decomposition reactions at low temperature.

Additionally, we incorporate a small number of radiative association reactions, of the form:

$$A + B \rightarrow Z + \gamma,$$
 (12)

where γ is the radiated photon that carries the excess energy from the association. We appropriate the Kooij form for this reaction, as with 2-Body Neutral-Neutral reactions, in order to determine the rate constant $k_{\rm ra}$ [cm³ s⁻¹]. We then apply this rate constant, along with the rate constant for the corresponding three-body reaction, to the adduct form of the overall rate constant (Hébrard et al. 2013, their eq. (B.2)):

$$k = \frac{\left(k_0[M]F + k_r\right)k_\infty}{k_0[M] + k_\infty},\tag{13}$$

where the function F is from the Troe form of the transition from high to low pressure.

The rate constants for the forward reactions are given in Appendix A with the labels '2d' for the neutral species and '3i' for ion-neutral species. These reactions are reversed in the manner described by Appendix B. Reactions 1-420 are reactions of this type, for which each odd-numbered reaction gives the low-pressure rate constant k_0 [cm⁶ s⁻¹] and each even-numbered reaction gives the high-pressure rate constant k_∞ [cm³ s⁻¹]. Reactions labeled 'ra' are radiative association reactions, numbered 2974-2980.

2.3. Thermal Ionization & Recombination Reactions

A special set of three-body reactions are thermal ionization and three-body recombination re-

actions, which proceed by the pair of equations (analogous to Eq's (7) and (8)):

$$A + M \rightarrow Z^{+} + e^{-} + M,$$
 (14)

$$A^{+} + e^{-} + M \to Z + M.$$
 (15)

For which we again use published rates wherever possible for the ionization reactions, (Eq. (14)), but in many cases here use the simple approximation:

$$k_0 = \left(\frac{8\pi e^8}{m_e k_B T}\right)^{1/2} e^{-I/k_B T},$$
 (16)

where $e = 4.9032 \times 10^{-10}$ esu is the elementary charge, $k_B = 1.38065 \times 10^{-16}$ erg/K is the Boltzmann constant, $m_e = 9.1084 \times 10^{-28}$ g is the mass of the electron, I is the ionization energy (here in units of erg) which we determine from the change in the Gibbs free energy for the reaction. k_{∞} is then estimated from k_0 .

Three-body recombination and ionization reactions have been well studied, and in many cases have well-characterized rate constants. Here we treat the three body recombinations as the reverse reactions for the collisional ionization reactions, but the studied rate coefficients for these reactions generally have a temperature dependence of $T^{-4.5}$, at least for T > 1 K (Hahn 1997). This creates a problem for reversibility. Using these rates will not allow us to reproduce chemical equilibrium for plasmas and this is largely because we are not properly treating the time-dependent plasma conditions in which these rates are often measured. Many of these rate constants may accurately describe the time to achieve an equilibrium electron density in a regime where a strong ionizing source has recently been removed from the environment.

With this in mind, we instead set the recombination rate constants such that, when dissociative recombination reactions are disabled, the Saha equation is upheld.

These reactions and rate coefficients are also given in Appendix A. The ionization reactions are labeled 'ti' and numbered 421-576. As with Section 2.2, the odd reactions are k_0 [cm⁶ s⁻¹] and the even numbers are k_{∞} [cm³ s⁻¹].

Finally, we include a series of dissociative recombination reactions, which take the form:

$$A^{+} + e^{-} \to Y + Z.$$
 (17)

These have rate constants parameterized in the form of Eq. (5). The reverse reactions can in principle be calculated, and their rate constants could be calculated straight-forwardly using the same principles used for the three-body reactions. This would effectively be analogous to the rates of three body recombination for any third body, and we do not find that reversing these reactions changes the results much. When we compare with chemical equilibrium, however, we disable these reactions. The dissociative recombination reactions are taken only from the OSU 09 2010 high temperature network (Harada et al. 2010), and shown in Appendix A, numbered 2777-2973, and labeled 'dr'.

2.4. Photochemistry and Cosmic Ray Chemistry

Photochemistry is considered for the species H, H⁻, He, C, C(1 D), C(1 S), N, O, O(1 D), O(1 S), H⁻, C₂, CH, CN, CO, H₂, N₂, NO, O₂, OH, CO₂, H₂O, HO₂, HCN, NH₂, NO₂, O₃, C₂H₂, H₂CO, H₂O₂, NH₃, NO₃, CH₄, HCOOH, HNO₃, N₂O₃, C₂H₄, C₂H₆, CH₃CHO, C₄H₂, C₄H₄, Na, K, and HCl. The photoionization and photodissociation cross-sections are taken almost entirely from PHIDRATES⁴ (Huebner & Carpenter 1979; Huebner et al. 1992; Huebner & Mukherjee 2015), with the exception of C₄H₂, C₄H₄ and N₂O₃, the cross-sections of which are taken from the MPI-Mainz UV/VIS Spectral Atlas⁵ (Keller-Rudek et al. 2013).

We divide the cross-sections between 200 bins each ≈ 50 Å wide. A comparison between our binned cross-sections and the raw cross-sections from PhIDRates is plotted for an example reaction (Figure 1). The cross-sections, both in the database and here, of the form $\sigma(\lambda)$ with σ in units cm² and wavelength in units of Å. The resolution for the UV cross-sections is fairly low, and cannot encapsulate the fine structure of the UV emission lines or the UV cross-sections. This is especially important when treating ionospheres of gas giants, since, e.g. the fine structure in the H₂ bands leave small spectral windows through which photons can penetrate and effectively ionize deeper in the atmosphere. Such a low resolution spectrum will effectively close these windows

 $^{^4}$ phidrates.space.swri.edu

 $^{^5 {\}it http://satellite.mpic.de/spectral_atlas/index.html}$

and underestimate the ion production in the ionosphere (Kim & Fox 1994; Kim et al. 2014). High resolution is also a important for capturing where the UV flux and cross sections both peak; a low resolution cross section can in this case underestimate the destruction rate of the species with this resonant photochemical cross-section. As can be seen below, these issues do not significantly affect the comparisons of this model for HD209458b, Jupiter or Earth. For photoionization deep in the atmosphere, where high resolution is essential, the network itself need not be modified. The transport of UV photons line by line would need to be calculated.

The tabulated chemical cross-sections are combined with $F(\lambda, z)$ [photons cm⁻² s⁻¹ Å⁻¹], the radiant flux density onto a unit sphere (hereafter called the actinic flux) located at atmospheric height, z [cm], to determine the photochemical rate constants.

$$k_{\mathrm{ph},i}(z) = \tau_f \int_{1\stackrel{\wedge}{A}}^{10^4 \stackrel{\wedge}{A}} \sigma_i F(\lambda, z) \, d\lambda, \qquad (18)$$

where i is indexed over the molecules listed above, for which photochemistry is considered. τ_f is a dimensionless parameter representing the fraction of time (over a period much longer than the longest characteristic time scale for the atmosphere) the particular atmospheric region is irradiated; for tidally locked planets, $\tau_f = 1$ (dayside) or 0 (nightside), the diurnal average for a rotating planet is $\tau_f = 1/2$. The photoionization and photodissociation reactions are listed in Appendix A, reactions numbered 2570-2693, and labeled 'pi' for photoionization reactions & 'pd' for photodissociation reactions.

Cosmic ray ionization and dissociation is parameterized by ζ (Rimmer & Helling 2013), to treat both direct ionization by galactic cosmic rays and ionization by secondary particles produced in air showers. The cosmic ray ionization rate depends on the chemical species in question, since different species will have different chemical cross-sections for the photons produced by cosmic rays, and this is accounted for by multiplying $\zeta(z)$ by a constant $\kappa_{\text{CR},i}$ such that:

$$k_{\mathrm{CR},i}(z) = \kappa_{\mathrm{CR},i}\zeta(z).$$
 (19)

We treat low energy cosmic rays (E < 1 GeV) for these objects as though they have been sig-

nificantly shielded by the astrospheres of the host stars, and therefore set the fitting parameters for the incident cosmic ray flux to $\alpha=0.1$ and $\gamma=-1.3$ in the equation for the flux of cosmic ray particles:

$$j(E) = \begin{cases} j(E_1) \left(\frac{p(E)}{p(E_1)}\right)^{\gamma}, & \text{if } E > E_2\\ j(E_1) \left(\frac{p(E_2)}{p(E_1)}\right)^{\gamma} \left(\frac{p(E)}{p(E_2)}\right)^{\alpha}, & \text{if } E_{\text{cut}} < E < E_2\\ 0, & \text{if } E < E_{\text{cut}} \end{cases}$$
(20)

where $p(E) = \frac{1}{c}\sqrt{E^2 + 2EE_0}$, $E_0 = 9.38 \times 10^8$ eV, $E_1 = 10^9$ eV, and $E_2 = 2 \times 10^8$ eV, and the flux at E_1 is set to $j(E_1) = 0.22$ cm⁻² s⁻¹ sr⁻¹ (GeV/nucleon)⁻¹. All of these parameters except α are observationally well-constrained (Indriolo et al. 2009). For a demonstration of how α affects the cosmic ray spectrum, and a discussion of the Monte Carlo transport we use for cosmic rays of energy < 1 GeV, see Rimmer et al. (2012); Rimmer & Helling (2013). For ionization rate by cosmic rays of energy > 1 GeV, $Q_{\rm HECR}$ [cm⁻³ s⁻¹], we use the analytical method of Velinov & Mateev (2008).

Cosmic ray reactions are listed in Appendix A, numbered 2694-2776, and labeled 'cr'.

2.5. Test for Chemical Equilibrium

At sufficiently high temperatures and pressures, a gas should rapidly settle into chemical equilibrium. An important test for a chemical network is that its steady state solution converges to the chemical equilibrium solution. To perform this test of our network, we solve the chemical kinetics at a single (T,p) point, using the rate constants from the STAND2015 network, disabling the cosmic ray reactions, photochemistry and dissociative recombination. We compute a time-dependent solution of the equation

$$\frac{dn_i}{dt} = P_i - L_i. (21)$$

We solve this equation for $T=1000~{\rm K}$ and p=1 bar, with solar abundances from Asplund et al. (2009). We compare our results to chemical equilibrium calculations using the Burcat polynomials (Burcat & Ruscic 2005), and plot our comparisons in Figure 2 and find excellent agreement. This agreement is not surprising; we have used the same

thermochemical data to reverse our reactions, and only include reversed reactions in this test, so once the system achieves steady state, computationally achievable at this pressure and temperature, the chemistry has effectively settled into equilibrium.

We also compare our electron number density to the electron number density achieved using the Saha equation, this time at a pressure of 10^{-4} bar and over a range of temperatures from 1000 K to 10000 K. This comparison is plotted in Figure 3. The comparison is virtually perfect when $T \gtrsim 2000 \text{ K}$, unsurprising given the way the threebody recombination reactions are calculated (see Section 2.3). At ~ 1000 K, our results diverge from the Saha equation. This is because the integrator does not reliably calculate mixing ratios below $\sim 10^{-30}$. Indeed, at this stage, the electron number density achieves $\sim 10^{-300}$ cm⁻³ while the H⁺ number density rests at $\sim 10^{-60}$ ${\rm cm}^{-3}$, producing significant charge balance errors. These large errors in the charge balance fluctuate, and only appear when the ionization fraction is $\lesssim 10^{-30}$, at which point ion-neutral chemistry is inconsequential.

3. 1-D Photochemistry/Diffusion Code

We have developed a simple 1D photochemistry/diffusion code (Argo), for the purposes of testing the Stand2015 network. The required inputs for Argo are:

- (p,T) profile of the atmosphere.
- Vertical eddy diffusion $(K_{zz} [\text{cm}^2 \text{ s}^{-1}])$ profile of the atmosphere (see discussion in Lee et al. 2015).
- Atmospheric elemental abundances.
- Boundary conditions at top and bottom of the p, T profile.
- Actinic flux⁶ at the top of the atmosphere.
- Chemical Network (in our case, Stand2015).
- Initial chemical composition

All of these inputs except the chemical composition are fixed.

With these inputs, ARGO solves molecular transport in a fully Lagrangian manner, similar to Alam & Lin (2008) and Zahnle et al. (1995). The model consists of two parts: (1) A chemical transport model (Section 3.1) and (2) calculation of the photochemical and cosmic ray chemical rate constants from cross-sections and a depth-dependent actinic flux (Section 3.2). A conceptual illustration is shown in Figure 4.

3.1. The Continuity Equations for Chemical Species

The coupled 1D continuity equations describing the time-dependent vertical atmospheric chemistry are:

$$\frac{\partial n_i}{\partial t} = P_i - L_i - \frac{\partial \Phi_i}{\partial z},\tag{22}$$

where n_i [cm⁻³] is the number density of species i, and $i = 1, ..., N_s$, and N_s is the total number of species. P_i [cm⁻³ s⁻¹] is the rate of production and L_i [cm⁻³ s⁻¹] is the rate of loss of species i. The right-most term is the vertical change in flux Φ_i [cm⁻² s⁻¹], and represents the flux due to both eddy (K [cm² s⁻¹]) and molecular diffusion (D [cm² s⁻¹]) respectively, related as (Banks & Kockarts 1973, their Eq. (15.14)),

$$\Phi_{i} = -K \left[\frac{\partial n_{i}}{\partial z} + n_{i} \left(\frac{1}{H_{0}} + \frac{1}{T} \frac{dT}{dz} \right) \right]
-D \left[\frac{\partial n_{i}}{\partial z} + n_{i} \left(\frac{1}{H_{i}} + \frac{1 + \alpha_{T}}{T} \frac{dT}{dz} \right) \right], \quad (23)$$

where $H_0[\mathrm{cm}]$ is the pressure scale height of the atmosphere at z [cm], $H_i[\mathrm{cm}]$ is the molecular scale height of the atmosphere for species i, and α_T is the thermal diffusion factor (Banks & Kockarts 1973; Yung & Demore 1999; Zahnle et al. 2006; Hu et al. 2012). For molecular diffusion coefficients, we adopt Chapman-Enskog theory (Enskog 1917; Chapman & Cowling 1991). Eddy diffusion coefficients are either determined empirically, as with Earth and Jupiter, or are derived from global circulation models, as is the case for HD209458b.

In Eq. (23), the terms dealing with eddy diffusion and molecular diffusion are separated out, clarifying four regions that Eq's (22), (23) describe. (1) Deep within the atmosphere, where pressures and temperatures are sufficiently large,

⁶The actinic flux is the radiance integrated over all angles, expressing flow of energy through a unit sphere. There are subtle differences between the actinic flux and the spectral irradiance, see Madronich (1987).

the thermochemistry dominates, and the equation simplifies to Equation (21). spheric chemical composition converges to chemical equilibrium or at least to some stable quasiequilibrium. (2) Higher in the atmosphere, the eddy diffusion may dominate, and the species are quenched, their abundance mixed evenly over a wide range of the atmosphere at time-scales shorter than the chemical time-scales. (3) Above this region, molecular diffusion may dominate, and at that point, species lighter than the mean molecular mass of the atmospheric gas will rise up, and species heaver than the mean molecular mass will settle down, and the chemistry will largely be determined by the individual scale heights of the atmospheric constituents. (4) Non-equilibrium processes, such as photochemistry or cosmic ray chemistry, may create a fourth region, the composition of which is determined by irreversible chemical reactions.

Since the purpose of this paper is to introduce a new chemical kinetics network for lightning and prebiotic processes, our focus is not on the atmospheric dynamics (for this, see Lee et al. 2015). We therefore apply a simple approximation to Eq. (22), inspired by Alam & Lin (2008). We first cast Eq. (22) in a Lagrangian formulation, and consider Eddy diffusion to be moving small parcels of the gas vertically. We follow a single parcel as it moves up from the lower boundary of the temperature profile, and then returns down again. In reality, the parcel would be jostled in all three dimensions as it makes a complex journey up to the top of the atmosphere, but 1D transport models are unable to capture this effect in full.

The differential diffusion of molecules into and out of the parcel requires a different approach. The discrete formulas used by Hu et al. (2012, their Eq. 9) in the Lagrangian frame are:

$$\frac{\partial n_{i,j}}{\partial t} = P_{i,j} - L_{i,j} n_{i,j} - d_{j+1/2} \frac{n_{\text{gas},j+1/2}}{n_{\text{gas},j+1}} n_{i,j+1}
- \left(d_{j+1/2} \frac{n_{\text{gas},j+1/2}}{n_{\text{gas},j}} - d_{j-1/2} \frac{n_{\text{gas},j-1/2}}{n_{\text{gas},j}} \right) n_{i,j}
+ d_{j-1/2} \frac{n_{\text{gas},j-1/2}}{n_{\text{gas},j-1}} n_{i,j-1}.$$
(24)

Here, j represents the parcel being followed, j-1 the parcel directly beneath j, j+1 the parcel above j, and $j\pm 1/2$ an arithmetic average between j and $j\pm 1$. n without any i subscript represents $n_{\rm gas}$ at

the relevant parcel, and

$$d_{j\pm 1/2} = \frac{D_{j\pm 1/2}}{2(\Delta z)^2} \left[\frac{(\bar{m} - m_i)g\Delta z}{k_B T_{j\pm 1/2}} - \frac{\alpha_T}{T_{j\pm 1/2}} (T_{j\pm 1} - T_j) \right].$$
(25)

 $\bar{m}[g]$ denotes the mean molecular mass of the atmosphere at z and $m_i[g]$ the mass of species i.

Both the third and last terms on the R.H.S. of Eq. (24) do not depend on n_i and can therefore be treated as source terms, P_i . The fourth term can be treated as a term in L_i , such that molecules "destroyed" by this reaction are "banked", A \rightarrow BA. The "banked" molecules re-enter the parcel at a rate determined by the third and last terms on the R.H.S. of the equation, thus conserving mass throughout the parcel's travels. Violations of this conservation do not appear here, but can be accounted for via further reactions, settling, condensation and evaporation, outgassing and escape, discussed in Appendix C. Although it is straightforward to handle atmospheric escape with this method, we do not do so for any of the test cases in this paper.

Equation (24) is solved within Argo in the same numerical manner as Nahoon (Wakelam et al. 2012), by the implicit time-dependent Gear method as incorporated by the Livermore Solver for Ordinary Differential Equations (DLSODE) (Gear 1971; Brown & Hindmarsh 1989).

3.2. Calculating the XUV and Cosmic Ray Flux

Once the fluid parcel has completed the atmospheric profile, the solar XUV actinic flux from 1 Å to 10000 Å as a function of depth, z [cm]⁷ and wavelength λ [Å] is calculated. We consider both the direct and approximate diffusive actinic flux. The local height-dependent actinic flux is calculated without any iteration on the local temperature. The cross-sections for various photochemical reactions (Sect. 2.4), are multiplied by each vertical step $(\Delta z)_j$ [cm], where $(\Delta z)_j$ is the size of the step at height z_j . The total optical depth as a function of the wavelength takes the form

$$\tau(\lambda, z) = \sum_{j} \left[(\Delta z)_{j} \sum_{i} \sigma_{i} n_{ij} \right] + \tau_{s}, \qquad (26)$$

⁷The depth for this model extends from z=0, the bottom of the temperature profile for the planet in question, to $z=z_{\rm top}$, the top of the profile.

where i is summed over all species for which photoabsorption is considered (see Section 2.4 for a list of these species). τ_s is the optical depth due to Rayleigh scattering, and the actinic flux as a function of depth is defined as (Hu et al. 2012):

$$F(\lambda, z) = F(\lambda, z_{\text{top}})e^{-\tau(\lambda, z)/\mu_0} + F_{\text{diff}}, \quad (27)$$

where $\mu_0 = \cos \theta$, where θ is the stellar zenith angle; we set $\mu_0 = 1/2$ for all calculations within this paper (see Hu et al. 2012, their Fig. 7). F_{diff} denotes the actinic flux of the diffusive radiation, determined using the δ -Eddington 2-stream method (Toon et al. 1989). Once the actinic flux is calculated, the photochemical rates are determined as in Section 2.4. Once the depth dependent flux, $F(z,\lambda)$ [cm⁻² s⁻¹ Å⁻¹], is determined for all layers, the parcel's path through the atmospheric profile is repeated, now accounting for the photochemistry. The cosmic ray ionization rate, $\zeta(z)$ [s⁻¹] is likewise calculated in a depth-dependent manner following Rimmer & Helling (2013) and incorporated into the chemistry (Sec. 2.4).

A new depth-dependent composition is constructed, then applied to Eq. (26) to solve again for $F(z,\lambda)$. The value of $\zeta(z)$ does not change significantly between iterations. This process is repeated until the results converge; i.e. until the profile from the previous global calculation (transport + depth-dependent flux) agrees to within 1% the profile from the current global calculation. The number of repetitions depends on the parameters, but is typically between 5 and 12 global iterations. This iterative process is represented as a flow-chart in Figure 5.

This method is both simple and functional, requiring relatively little computational resources. It is also straight-forward to adapt to diverse chemical environments, since it does not require the selection of "fast" and "slow" chemistry to ease computational speed. These strengths do not come without a cost: The simplistic dynamics does not transition as smoothly from the eddy diffusion regime to the molecular diffusion regime as the Eulerian formulation, and can result in steep changes over a handful of height-steps.

3.3. Testing the Atmospheric Transport Model for Molecular Diffusion

In order to benchmark the STAND2015 chemical network in different planetary atmospheres, we

test the molecular diffusion within Argo. We consider a 1D isothermal gas under a constant surface gravity, $g=10^3~{\rm cm/s^2}$, with temperature $T=300~{\rm K}$, at hydrostatic equilibrium. The gas is initially composed of carbon and hydrogen atoms, each with a mixing ratio of $X_0({\rm C})=n({\rm C})/n_{\rm gas}=0.5$ and $X_0({\rm O})=0.5$ throughout. All chemistry is disabled. It is expected that the heavier species, carbon, will settle into the atmosphere, and the lighter species, hydrogen, will rise up, until they stratify. The analytic solution to this system is well-known. The mixing ratio should be determined by the scale-heights of the individual species such that, for the carbon abundance:

$$X(C) = \frac{X_0(C)e^{-z/H_C}}{X_0(H)e^{-z/H_H} + X_0(C)e^{-z/H_C}}, \quad (28)$$

where X(C) is the final steady state carbon mixing ratio, and H_H [cm] and H_C [cm] are the atmospheric scale heights for the hydrogen and carbon.

The code is run until steady state is achieved, when the carbon in the very upper atmosphere diffuses into the lower atmosphere. The steady-state mixing ratio, as a function of height is compared the analytic mixing ratio, Eq. (28), in Figure 6. The comparison is reasonable through the extent of the atmosphere.

4. Testing the Network for Planetary Environments

The Stand2015 network contains chemical reactions for an H/C/N/O gas, and including both highly reducing to highly oxidizing atmospheres, and for a temperature range of 100 K to 30000 K. The network should then be tested for a variety of planetary atmospheres with different chemical compositions, from the (probably) oxidizing atmosphere of the early Earth to the highly reducing atmosphere of Jupiter. The large range of temperatures is tested for the irradiated exoplanet HD209458b. We also test our model against the height dependent measurements of select trace species within the atmosphere of the present-day Earth. It would be interesting to apply our model to Titan, due to its rich nitrile and organic chemistry. Titan's atmosphere is a very rich and complex environment, and it is important to account for these complexities when modeling Titan. Titan has upper atmospheric hazes, temperatures low enough to condense several molecular species, and ionization and dissociation by energetic particles including cosmic rays, Saturn magnetospheric particles, solar wind protons and interplanetary electrons. As useful as a study of the atmosphere of Titan would be for exploring Miller-Urey-like chemistry (Waite et al. 2007), such a model is beyond the scope of this paper. The boundary conditions for these various objects are given in Section 4.1. We then compare our results to the results from other chemical kinetics models and, where possible, with observations, for HD209458b (Section 4.2), Jupiter (Section 4.3), and the Earth (Section 4.4).

4.1. Boundary Conditions for Three Test Cases: HD209458b, Jupiter and the Earth

Below, we compare the results of our chemical kinetics to other results for HD209458b and also for Jupiter and the Earth. Each of these objects has different boundary conditions and parameters. These conditions and parameters include the temperature profile of the object's atmosphere, the eddy diffusion profile, the elemental abundances, the initial composition at the lower boundary of the atmospheric profile, and the unattenuated UV flux. For HD209458b, the conditions at the lower boundary of the atmospheric profile rapidly develop from the prescribed initial conditions toward chemical equilibrium. For Jupiter and the early Earth, the composition at the lower boundary is stable over the dynamical time-scale $(dn_i(z=0)/dt\approx 0)$, and so the initial composition effectively acts as a lower boundary condition. The assumed elemental abundances and initial conditions at the lower boundary of the atmospheric profile are given in Table 1.

We take HD209458b to have solar elemental abundances throughout its atmosphere, and set the initial conditions at the lower boundary of the atmosphere to be entirely atomic. The initial composition hardly matters here, since the composition quickly settles to chemical equilibrium at such a high temperature and pressure. The temperature profile and eddy diffusion profile for HD209458b are both taken from Moses et al. (2011), so that we can directly compare results.

Since HD209458 is a G0 star, we use the solar UV flux. The unattenuated solar UV flux

at 1 AU is obtained from the SORCE data (Rottman et al. 2006) for 1 Å - 350 Å and 1150 Å - 10000 Å with data from PhIDRATES for the 350 - 1150 Å range. The binned flux we use is plotted in Figure 7. This flux is adapted to HD209458b by multiplying the solar UV flux by a factor of $(d_{\oplus}/d_p)^2$, where d_{\oplus} [AU] is the distance from the Earth to the Sun and $d_p \approx 0.047$ AU is the approximate distance between HD209458b and its host star. This may not be the most accurate approximation to the UV behavior of HD209458, since it might have quite different activity from our sun (Tu et al. 2015).

For Jupiter, we use the temperature and eddy profiles from Moses et al. (2005). For consistency, we set the initial conditions at the lower boundary of Jupiter's atmosphere to be the same as Moses et al. (2005); see Table 1. The solar UV spectrum at 1 AU is used for Jupiter, although multiplied by a factor of $(d_{\oplus}/d_J)^{-2}$, where $d_J \approx 4.5$ AU is the square of the distance between the sun and Jupiter.

For the present-day Earth, we use the measured surface mixing ratios from the US Standard Atmosphere 1976 (see Table1) and the temperature profile from Hedin (1987, 1991), Fig. 13. We use the present day solar flux at 1 AU as our incident UV flux.

We use the same chemical lower boundary conditions as from Kasting (1993) for the atmosphere of the early Earth (Table 1). The temperature profile for the early Earth is assumed to be the same as that of the present Earth (Hedin 1987, 1991), Fig. 13. The UV field used for this model is that of the young Sun calculated using the scaling relationships of Ribas et al. (2005) for wavelengths between 1 Å – 1200 Å and the UV field of the solar analogue κ^1 Cet above 1200 Å (Ribas et al. 2010).

4.2. HD209458b

HD209458b was first observed by Henry et al. (2000), and is one of a growing number of Hot Jupiters to have a measured spectrum, via transit (e.g. Queloz et al. 2000), and also in emission (e.g. Knutson et al. 2008). Various molecular species have been tentatively identified in the spectrum, such as TiO (Désert et al. 2008), water (Madhusudhan & Seager 2009; Swain et al. 2009; Beaulieu et al. 2010), CO, CO₂ and methane fea-

tures (Madhusudhan & Seager 2009; Swain et al. 2009). HD209458b has been extensively modeled, with retrieval modeling (Madhusudhan & Seager 2009), and with hydrodynamic global circulation models (Showman et al. 2008). This planet has also been a popular target for non-equilibrium chemistry models such as those of Liang et al. (2003); Zahnle et al. (2009); Moses et al. (2011); Venot et al. (2012); Agúndez et al. (2014) and Lavvas et al. (2014).

We have chosen the atmosphere of HD209458b as one candidate for benchmarking our results because it is well characterized and has been the subject of several non-equilibrium chemistry models, and it has a very high temperature even among Hot Jupiters. An additional benefit to HD209458b is its suspected temperature inversion (Knutson et al. 2008, although this is debated, see also Schwarz et al. 2015), which allows us to test our chemistry at very high temperatures both at both high and low pressures. The thermal profile of HD209458b from Moses et al. (2011) is shown in Figure 8. The local gas-phase temperature T > 2000 K both when p > 100 bar and when the gas-phase pressure, $p < 10^{-4}$ bar. This is a wide parameter space relevant for ion-neutral chemistry initiated via thermal ionization.

We compare our results to the predictions of two different chemical kinetics models. (1) We compare our results to the results of Moses et al. (2011) with the ion-neutral chemistry disabled. (2) We compare the ionic abundances for our most abundant ions to the results of Lavvas et al. (2014). Also in this case, we disable cosmic ray chemistry in order to draw a better comparison to the ion-neutral chemistry.

We compare our network and transport model to Moses et al. (2011) by examining the volume mixing ratios of major neutral species: H, H₂, He (hydrogen/helium chemistry), OH, H₂O, O and O₂ (oxygen/water chemistry), N₂ and NH₃ (nitrogen chemistry), and CO, CH₄ and CO₂ (carbon chemistry). See Figure 9. These species were chosen because they are abundant and, in the case of H₂ and N₂, play an important role in the nonequilibrium chemistry. N₂ provides the reservoir for the transition between N₂ \rightleftharpoons NH₃. Other species were chosen because they contribute to features observed in transit spectroscopy, (e.g. CO₂). The molecules CO and H₂O do both. Helium was

chosen because its mixing ratio is not significantly affected by the chemistry. It changes with pressure due to molecular diffusion, and so it provides a useful comparison between our dynamical calculations and those of Moses et al. (2011).

The transition of carbon between CO and CH₄, and nitrogen between N₂ and NH₃ is very sensitive to non-equilibrium chemistry, as $CH_4 \approx CO$ when $p \sim 100$ bar and $T \sim 2000$ K. As the pressure decreases rapidly while the temperature remains relatively high (T > 1000 K), the thermochemical equilibrium ratio for CH₄/CO plummets, approaching 10^{-7} at 0.1 bar in the HD209458b atmosphere. The time it takes the carbon to meander from CH₄ to CO, however, becomes significantly longer than the relevant dynamical timescales (for HD209458b, this time-scale is prescribed by the eddy diffusion coefficient, see Bilger et al. 2013), and the CH₄ and CO abundances are quenched. The same sort of process governs the transition of nitrogen from N_2 to NH_3 .

The pathways for both $CH_4 \rightleftharpoons CO$ and $N_2 \rightleftharpoons$ NH₃ interconversions are not well understood. In both cases, the paths competing with one another are often circuitous, and tend to be regulated by one of several reactions encountered along the journey, a slow rate-limiting step (Moses 2014). The time-scale of the transition between species is almost entirely set by the rate by which that single reaction proceeds. As discussed in Section 2, rate coefficients can be frustratingly uncertain, with different estimations sometimes varying by more than an order of magnitude. For example, compare the rate experimental and theoretical rate constants for $C_2H_6 \rightarrow CH_3 + CH_3$ (Yang et al. 2009 and Kiefer et al. 2005, respectively). The path that one believes regulates these central transitions can be very different depending on what rate coefficients are used.

An illustrative example is the reaction $CH_3 + H_2O \rightarrow CH_3OH + H$. Hidaka et al. (1989) has determined the rate for $CH_3 + H_2O \rightarrow Products$, Reaction (29), proceeds with a barrier of ≈ 2670 K (see Visscher et al. 2010, for a discussion on this reaction). With reasonable assumptions of the branching ratios for this reaction, namely that the branching ratios do not change much with temperature, one would set the same barrier to $CH_3 + H_2O \rightarrow CH_3OH + H$, as done by Venot et al. (2012). However, Moses et al. (2011)

carried out quantum chemical calculations for this reaction using MOLPRO and estimate a barrier for this particular branch of ≈ 10380 K, much larger than the activation energies of the other branches. With the smaller barrier, the path carbon takes from CH₄ to CO proceeds as:

$$H_{2} + M \rightarrow H + H + M$$

$$CH_{4} + H \rightarrow CH_{3} + H_{2}$$

$$CH_{3} + H_{2}O \rightarrow CH_{3}OH + H$$

$$CH_{3}OH + H \rightarrow CH_{2}OH + H_{2}$$

$$CH_{2}OH + M \rightarrow H_{2}CO + H_{2} + M$$

$$H_{2}CO + H \rightarrow HCO + H_{2}$$

$$HCO + H \rightarrow CO + H_{2}$$

$$HCO + M \rightarrow CO + H + M$$

$$(29)$$

(30)

We adopt the rates of Moses et al. (2011) for this pathway, as well as the smaller rate coefficient for the three-body reaction $H_2O + CH_2 + M \rightarrow CH_3OH$. An examination of our results would reveal that, as with Venot et al. (2012), the transition of carbon from CH_4 to CO is much more efficient than with Moses et al. (2011). We have examined the rates at which reactions proceed in our network and find another formation pathway:

 $CH_4 + H_2O \rightarrow CO + 3H_2$.

$$H_{2} + OH \leftrightarrow H_{2}O + H$$

$$OH + O \rightarrow O_{2} + H$$

$$CH_{4} + H \rightarrow CH_{3} + H_{2}$$

$$CH_{3} + H \rightarrow CH_{2} + H_{2}$$

$$CH_{2} + O_{2} \rightarrow COOH + H$$

$$COOH + H_{2}O \rightarrow CH_{2}O_{2} + OH$$

$$CH_{2}O_{2} + M \rightarrow CO_{2} + H_{2} + M$$

$$CO_{2} + H \rightarrow CO + OH$$

$$(31)$$

The atomic oxygen arises from thermal dissociation of OH or photodissociation of H_2O followed by diffusion downward. This pathway is critically dependent on Reaction (31). To our knowledge, the three-body rate coefficient for this reaction has not been determined. This reaction has instead appeared in our network as the reverse reaction of $CH_2O_2 + OH \rightarrow COOH + H_2O$, for which

 $CH_4 + O \rightarrow CO + 2H_2$,

we use an estimate based on reaction energetics (Mansergas & Anglada 2006). This pathway is highly uncertain, and removing it makes up the majority of the difference between our results and those of Moses et al. (2011) for methane between $1-10^{-4}$ bar. We suspect further differences owe to our different thermochemical constants and the use of slightly different solar abundances.

The path of nitrogen from NH₃ to N₂ is considerably more uncertain. The path is believed to roughly follow from NH₃ to NH via hydrogen abstraction, which will in turn react with another NH_X species to form N₂H_Y. This species will be destroyed either by reacting with hydrogen or via thermal decomposition, to form N₂. The reactions N₂H_{X+2} \rightarrow NH₂ + NH_X involve large uncertainties, which result in variations of the NH₃ quenched abundance by an order of magnitude. We find, similar to Moses et al. (2011), that:

$$H_{2} + M \rightarrow H + H + M$$

$$NH_{3} + H \rightarrow NH_{2} + H_{2}$$

$$NH_{2} + H \rightarrow NH + H_{2}$$

$$NH_{2} + NH \rightarrow N_{2}H_{2} + H$$

$$N_{2}H_{2} + H \rightarrow NNH + H_{2}$$

$$NNH + M \rightarrow N_{2} + H + M$$

$$2NH_{3} \rightarrow N_{2} + 3H_{2}$$
(34)

with Reaction (33) as the rate limiting step. The profile we have for NH₃ deviates considerably from the results of Moses et al. (2011), but this is for large part due to a difference in the nitrogen thermochemistry and initial abundances at high pressures propagating up through the atmosphere. Figure 9 shows that our quenching height is in both cases higher than for Moses et al. (2011), suggesting that the nitrogen in NH₃ migrates to N₂ more slowly in our network, even overtaking Moses et al. (2011) at $\sim 10^{-4}$ bar, but that we start with less NH₃ than Moses et al. (2011). The increase in NH₃ abundance at $\sim 5 \times 10^{-6}$ bar is due to a formation path for NH₃ in Moses et al. (2011) that is less efficient in our network.

We conclude this section with a brief discussion of the most neutral ions, in comparison with Lavvas et al. (2014). We have plotted the most abundant ions in Figure 10. Note that, for this paper, $n_{\rm gas}$ is a sum of all neutral gas particles,

(32)

cations, ions and electrons, so the mixing ratio of ions cannot increase above unity. This plot allows a direct comparison to Lavvas et al. (2014, their Fig's 5 & 6). In our model, K^+ is the most abundant ion deep within the atmosphere, followed by Mg⁺ and Fe⁺. Lavvas et al. (2014) does not consider these species, but they don't seem to affect the abundances of other ions very much deep within the atmosphere. When the pressure delves to 10⁻² bar, K⁺ deviates considerably between our results and those of Lavvas et al. (2014). This is likely due to the inclusion of several other ions in our model that become dominant charge carriers at this height, including several complex hydrocarbon ions, of the form $C_nH_m^+$. This indicates that ion-neutral chemistry can be significantly influenced by the variety of ions and neutral species under consideration. This will be especially true for the potassium chemistry. Our network contains a small number of potassium-bearing species. Including new species and reactions could significantly affect the degree of ionization. It will be interesting to discover how an expanded potassium and sodium chemistry affects the overall ionneutral chemistry and the resulting abundances of trace species.

Between 10^{-3} and 10^{-4} bar, Na⁺ overtakes K⁺ as the dominant positive charge carrier, and remains so until $\sim 10^{-7}$ bar. This transition, the ratios between the ions, and the abundances of the ions, are nearly identical between our model and that of Lavvas et al. (2014). Within the thermosphere of HD209458b, there are some small discrepancies between our model and Lavvas et al. (2014) for He⁺, and quite large discrepancies for C⁺ which we suggest are owing to the non-Alkali photochemistry that Lavvas et al. (2014) include, but that we have not included here.

4.3. Jupiter

The atmosphere of Jupiter is divided into three regions: (1) the troposphere, where the gas-phase temperature T decreases with atmospheric height, (2) the stratosphere, where T is roughly constant with increasing height, and (3) the thermosphere, where T increases with height. In this section, we consider the chemical composition of Jupiter's stratosphere. The stratosphere of Jupiter is rich in hydrocarbons, owing to its large gas-phase C/O ratio, because the majority of the

oxygen is locked in water ice and then gravitationally settling to below the tropopause. This is predicted to lead to a C/O $\sim 2 \times 10^6$ (Moses et al. 2005) in the absence of external sources of H₂O and CO₂ (Feuchtgruber et al. 1997; Moses et al. 2000a,b) such as Shoemaker-Levy 9 (Cavalié et al. Jupiter's stratosphere provides an extreme example of how surface deposition can radically affect the C/O ratio, an effect more recently predicted for exoplanets and brown dwarfs (Bilger et al. 2013; Helling et al. 2014). The high C/O ratio, in combination with the large abundance of hydrogen (H₂ and CH₄ are the two most abundant volatiles in the stratosphere and lower thermosphere), means that the stratosphere of Jupiter is strongly reducing (Strobel 1983).

Fouchet et al. (2000) have observed ethane and acetylene in Jupiter's stratosphere. Ethylene has also been observed by Bézard et al. (2001). The stratospheric chemistry of Jupiter has been modeled by several groups, including Gladstone et al. (1996) and Moses et al. (2005). We adopt the lower boundary conditions and temperature profile that Moses et al. (2005) used and model the carbon-oxygen chemistry in the stratosphere of Jupiter, ignoring the nitrogen chemistry (most of the nitrogen will be locked in NH₃ ice). Boundary conditions are discussed in Section 4.1.

Our lower boundary is set to be identical to Moses et al. (2005). These boundary conditions are somewhat artificial; the carbon budget is controlled by the photochemistry and the dynamics. There is no effective destruction pathway for the stable hydrocarbons, but the time-scale for their formation is often competing with the dynamical time-scales. In the thermosphere, $\sim 10^{-7} - 10^{-8}$ bar, these hydrocarbons are lost through photodissociation and photoionization as well as molecular diffusion. At the base, the chemistry is halted once the dynamical timescale is reached, effectively treating the bottom boundary as an open boundary through which the hydrocarbons would continue to diffuse. In reality, the complex hydrocarbons are carried into Jupiter's deep atmosphere, where the high temperatures and pressures dissociate these hydrocarbons, and force the carbon budget to return to chemical equilibrium values: CH₄ with trace amounts of CO and other species. Visscher et al. (2010, their Fig. 6) demonstrate how the carbon budget is set deep within Jupiter's

atmosphere; we do not model this region.

With these reactions removed from the network, we ran the network using the temperature and $K_z z$ profiles from Moses et al. (2005), shown in Figure 11. Comparisons between our results and a representative set of observations for the depth dependent mixing ratios, for the species CH_4 , C_2H_2 , C_2H_4 , C_2H_6 and C_4H_2 , are shown in Figure 12. The observations for CH_4 are taken from Drossart et al. (1999) and Yelle et al. (1996), C₂H₂ observations are from Fouchet et al. (2000), Moses et al. (2005) and Kim et al. (2010), C_2H_4 observations are from Romani et al. (2008) and Moses et al. (2005), C_2H_6 observations are from Fouchet et al. (2000), Moses et al. (2005), Yelle et al. (2001) and Kim et al. (2010), and the C_4H_2 observations are from Fouchet et al. (2000) and Moses et al. (2005). We also incorporate observations for C₂H₂, C₂H₄ and C₂H₆ from Gladstone et al. (1996) and references therein.

Many of the published observations do not include error bars in atmospheric pressure. ditionally, there may seasonal in the pressuretemperature structure and the location of the homopause, which adds uncertainty to our predictions as a function of pressure. To account for these sources of uncertainty, we place error bars for the pressure at a factor of two above and below the published observations when errors in pressure were not given. These errors in pressure are of the same order as observations where errors in pressure are given. We do not compare our results for oxygen-bearing species, because the abundances of these species are expected to be greatly enhanced in the stratosphere by the addition of an external source of oxygen, such as Shoemaker-Levy 9.

The differences between our results and those of other models arise primarily because of different photochemistries and different rate constants, especially for the re-formation of methane after its photodissociation,

$$CH_3 + H_2 \rightarrow CH_4 + H$$
, and (35)

$$CH_3 + H + M \rightarrow CH_4 + M. \tag{36}$$

Differences between Jovian photochemical models can result in very large discrepancies between stratospheric abundances of complex hydrocarbons. The differences between Gladstone et al. (1996) and Moses et al. (2005) span several orders

of magnitude in some cases (see Moses et al. 2005, their Fig. 14).

Both ethane and acetylene agree reasonably well between our model and the observations, and the results for C₄H₂ lie more than a factor of five below the observational upper limits. Our predictions for the location of the methane homopause do not agree very well with observations. We use the eddy diffusion coefficient from Model C in Moses et al. (2005), and either this or the use of the Chapman-Enskog diffusion coefficient for Methane may be the source of the discrepancy. Our results are similar to the Model C results of Moses et al. (2005, their Fig. 14). The molecule with the largest discrepancy between the two models is ethylene (C_2H_4) , with the largest discrepancy between our predictions and the 1 millibar observations (ignoring the observation from Gladstone et al. 1996 that predicts a mixing ratio of $\sim 10^{-8}$). In our model, the primary path of formation for ethylene follows from the photodissociation of ethane (Reaction 2679 in the network),

$$C_2H_6 + \gamma \to C_2H_4 + H_2,$$
 (37)

and ethane is formed from CH₄ following paths to formation like this one:

$$2(CH_4 + \gamma \to {}^{1}CH_2 + H_2),$$

$$2({}^{1}CH_2 + H_2 \to CH_3 + H),$$

$$CH_3 + CH_3 + M \to C_2H_6 + M;$$

$$2CH_4 + 2\gamma \to C_2H_6 + 2H.$$
(38)

These differences may be resolved by a more careful accounting of pressure-dependent branching ratios, such as those of:

$$H + C_2H_5 \rightarrow CH_3 + CH_3 \tag{39}$$

from Loison et al. (2015). We use the Kooij form for these reactions (Section 2.1), which does not account for the effect that pressure has on the rate constant.

Ion-neutral chemistry also makes a contribution, via the formation of C_2H_4 from the reaction

$$CH_5^+ + C_2H_2 \rightarrow C_2H_3^+ + CH_4$$

 $C_2H_3^+ + e^- + M \rightarrow C_2H_3 + M$
 $C_2H_3 + CH_4 \rightarrow C_2H_4 + CH_3,$ (40)

and CH_5^+ forms from a series of reactions starting with the photoionization of CH_3 and then a series of hydrogen abstractions, $\mathrm{CH}_x^+ + \mathrm{H}_2 \to \mathrm{CH}_{x+1}^+ + \mathrm{H}$. It should be emphasized that this is not the primary formation pathway for ethylene, but it is an important path of formation in our chemistry and makes some contribution to the mixing ratios at 1 millibar.

Finally, there is a large discrepancy for CO, but this is not due to differences in the chemistry. Rather, this results from Moses et al. (2005) injecting CO, $\rm CO_2$ and $\rm H_2O$ into Jupiter's stratosphere. Inclusion of this external source of oxygenbearing species is justified by a number of datamodel comparisons mentioned at the beginning of this section. We neglected to include these external sources, and therefore oxygen-bearing species, especially $\rm H_2O$ and $\rm CO_2$ (not shown) fail to agree with observations. Our results therefore suggest that some external source of oxygen-bearing species is necessary to explain the $\rm H_2O$ and $\rm CO_2$ observations in Jupiter's stratosphere.

4.4. The Earth

The Earth's atmosphere is well studied, and the profiles of trace species are well constrained, and the formation and destruction of these species is controlled by photochemistry and deposition. Comparing our results to the present day Earth atmosphere therefore provides a comprehensive test of our chemical network (Section 4.4.1). Additionally, the connection between lightning-driven and NO_x chemistry⁸ has been extensively studied with experiments, observations and models, and provides a useful regime in which to compare the results of STAND2015 applied to a lightning shock model (Section 4.4.2). It is important to find out what our model predicts in habitable environments before the onset of life, and so we apply our model to the Early Earth (Section 4.4.3).

4.4.1. Present Day Earth Atmosphere

The best understood planetary atmosphere, in terms of both models and observations, is the atmosphere of the present day Earth. Earth's atmosphere has been studied *in situ*, with the use of countless balloon experiments used to mea-

sure various trace elements, and remotely, with satellite measurements. Models of Earth's atmosphere range from simple to complex, both dynamically (1D diffusion to 3D global circulation models) and chemically (from treating only oxygen and hydrogen chemistry to modeling the transport and chemistry of chlorofluorocarbons and biological aerosols). Seinfeld & Pandis (2006) provide a useful introduction and review to the subject.

Our interest is in validating our photochemical network to the present-day Earth, and not in coupling Earth's geochemistry to its atmospheric chemistry. We therefore make some simplifying assumptions when we set our boundary conditions. We compare our model to the contemporary Earth by setting the lower boundary conditions, temperature profile and external UV field as given in Section 4.1. We present these comparisons for O_3 , CH_4 and N_2O (Figure 14), NO and NO_2 (Figure 15) and OH and H_2O (Figure 16).

The data for O_3 , CH_4 and N_2O is taken from the globally averaged mixing ratios from Massie & Hunten (1981). Following Hu et al. (2012), we apply error bars spanning an order of magnitude in mixing ratio to reflect the temporal and spatial variations. Our model fits the measured CH₄ to within the error bars throughout the atmosphere. The O_3 predicted by the model deviates from the data with errors at 15 km, and the N₂O deviates from the data with errors between 40 km - 55 km. This may be due to an over-estimation of the optical depth. If more UV photons in the model penetrated through to ~ 10 km, the O_3 mixing ratios would be enhanced at 15 km, and the N₂O mixing ratios would be destroyed more efficiently deeper in the atmosphere.

The data for NO and NO_2 is taken from balloon observations at 35 deg N in 1993 (Sen et al. 1998), and here also we apply error bars spanning an order of magnitude to reflect spatial and temporal variations. As with Hu et al. (2012), we seem to overpredict the abundance of NO in the upper atmosphere (30-40 km). We find that this overprediction is due to Reaction 1300 in the network:

$$N_2O + O(^1D) \to NO + NO;$$
 (41)
 $k = 7.25 \times 10^{-11} \text{ cm}^3 \text{ s}^{-1}.$

We use the rate suggested by the JPL Chemical

⁸Referring primarily to NO and NO₂ chemistry.

Kinetics and Photochemical Data for Use in Atmospheric Studies (Sander et al. 2011). If the rate constant for this reaction is decreased by a factor somewhere between 2 and 10, we come into much better agreement at 30-40 km, and worse agreement between 20-30 km (see Figure 15).

Finally, the data from OH and H₂O was taken from balloon measurements at various latitudes and heights in 2005 (Kovalenko et al. 2007). We plot each individual datapoint without error bars in order to represent the observed variations; changes at other points of the globe or at other times of the year or day may lead to more significant variations in the abundances. The H₂O predictions are within a factor of five of the observed water abundance, and our OH predictions lie within the measurements, indicating that the model correctly reproduces the water and OH mixing ratios.

4.4.2. Lightning Shock Model and NO_x chemistry

It is also useful to to the model's NO_x lightning-driven chemistry in the present day atmosphere. For this purpose, we apply a simple shock model in order to explore the formation of NO_x species due to lightning at a single small region in the atmosphere. We employ the temperature and pressure calculations of Orville (1968, his Fig's 1 and 3) and the time-scaled results of Jebens et al. (1992, their Fig's 2 and 3), fitting these to an exponential function. We use the following functions of temperature and pressure:

$$T(t) = 300 \,\mathrm{K} + (29800.0 \,\mathrm{K}) \,e^{-t/(55.56 \,\mu\mathrm{s})};$$
 (42)

$$P(t) = 1.0 \,\text{bar} + (7.0 \,\text{bar}) \,e^{-t/(5.88 \,\mu\text{s})}.$$
 (43)

a We start with present day atmospheric chemistry at the base of the troposphere, except without the N_2O , NO and NO_2 species, and with $T=300~\rm K$ and p=1 bar. The shock occurs at 1 ns, and is allowed to evolve until 0.1 ms. At this point the calculation is terminated, and another calculation initiated using for its initial conditions the final conditions of the shock model, except with temperature and pressure returned to 300 K and 1 bar, respectively. This model is run until $10^4~\rm s$ and results are shown in Figure 17.

We find that the NO_x species are formed in our model thermally by the Zel'dovich mechanism (Zel'dovich & Raizer 1966):

$$O_2 + M \rightleftharpoons O + O + M,$$
 (44)

$$N_2 + M \rightleftharpoons N + N + M, \tag{45}$$

$$O + N_2 \rightarrow NO + N,$$
 (46)

$$N + O_2 \rightarrow NO + O,$$
 (47)

$$O_2 + N_2 \rightarrow 2NO.$$
 (48)

We compare our NO yield to the lightning discharge experiments performed by Navarro-González et al. (2001). We use for our NO mixing ratio the values found before the end of the shock (10^{-4} s in Fig. 17), between 10^{-2} and 10^{-3} , to (Navarro-González et al. 2001, their Eq. 4). We find that:

$$P(\text{NO}) \approx (2.4 \times 10^{22} \,\text{K/J}) \frac{X(\text{NO})}{T_f}$$
$$\approx 2 - 20 \times 10^{16} \,\text{molecules J}^{-1}, \quad (49)$$

where T_f [K] is the "freeze-out" temperature after which the NO mixing ratio does not change appreciably over the time-scale of the experiment, which we set to 1000 K (the approximate temperature of our model at $t \approx 10^{-4}$ s). This is consistent with the production of NO in the "hot core" region of the experiment. This is also roughly consistent with the literature values for NO production of 10^{17} molecules J^{-1} (Borucki et al. 1984; Price et al. 1997).

This is an order-of-magnitude comparison between the code and lightning experiments and models, and for a more complete comparison will need to be applied to a model atmosphere, where diffusion and photochemistry together will further process the NO_x species. We plan to do this in a future paper.

4.4.3. The Early Earth

The presence of life and the evolution of the sun both have radically altered Earth's atmospheric chemistry. Oparin (1957) and Miller & Urey (1959) thought that the atmosphere of the early Earth⁹ was largely reducing, dominated by methane, ammonia and molecular hydrogen. Kasting (1993) made a compelling case

 $^{^9\,\}mbox{``early Earth"}$ in this context means the Earth in its first 1 $\,{\rm Gyr}$

that prebiotic formation of hydrogen would be too slow to allow for much molecular hydrogen in the atmosphere of the early Earth. Furthermore, a major constituent in the early Earth atmosphere needs to be a strong greenhouse gas, in order to compensate for the cooler young sun. The atmospheric chemistry of the early Earth is difficult to determine, and a severe lack of data results in many possible early Earth chemistries. As an illustrative example, Tian et al. (2005) argue that hydrogen escape was less efficient during the first 1 Gyr as was previously thought¹⁰. If Tian et al. (2005) are correct, then Earth's early atmospheric composition could have been reducing.

We present a model of the atmosphere of the early Earth, using the same lower boundary conditions as shown in Kasting (1993, his Fig. 1), and a temperature profile for the present Earth (Hedin 1987, 1991)¹¹, shown in Figure 13. The lower boundary conditions used for the early Earth are given in Section 4.1. We treat outgassing using the deposition method (Appendix C).

We compare our results to those of Kasting (1993, esp his Fig. 1). Our results are presented in Figure 18. The results compare reasonably well for CO and O_2 , but not for H_2O and O. The CO abundance begins to increase at 30 km, 10 km higher than for Kasting (1993), and achieves a mixing ratio of $\approx 5 \times 10^{-3}$ at 60 km, which is within a factor of 2 of Kasting (1993). The O₂ likewise begins to rise above a mixing ratio of 10^{-6} 10 km higher in the atmosphere, and also achieves a mixing ratio of $\approx 2.5 \times 10^{-3}$, again within a factor of 2 of Kasting (1993). The water vapor profile is quite different, however. Instead of falling below a mixing ratio of 10^{-6} at 10 km, the H₂O mixing ratio in our model levels out at 5×10^{-4} , increasing slightly at ~ 50 km before plummeting. Also, the oxygen mixing ratio only reaches $\approx 3 \times 10^{-6}$, approximately two orders of magnitude below the mixing ratio predicted by Kasting (1993). These differences may be due to the different assumed young solar UV fields between ourselves and Kasting (1993), but we suspect that the differences are more likely due either to differences in the water condensation or the temperature profiles used. This seems especially likely for atomic oxygen, which is primarily

destroyed by the reaction:

$$O + H_2O \rightarrow OH + OH,$$
 (50)

in spite of the sizeable 7640 K barrier. When the water vapor drops off at ~ 55 km, this destruction route becomes unviable, and the atomic oxygen mixing ratio rapidly increases. a

5. Glycine Formation in a Laboratory Environment

The formation of glycine, among several other amino acids, amines and nucleotides, has been investigated for a variety of chemical compositions, from reducing (Miller 1953) to oxidizing (Schlesinger & Miller 1983; Miyakawa et al. 2002; Cleaves et al. 2008), and exploring various energy sources (see Miller & Urey 1959, and references therein). In a recent experiment, HCN and $\rm H_2S$ were exposed to UV light (peak frequency 2540 Å), resulting in the formation of numerous complex prebiotic compounds (Patel et al. 2015). The techniques used in this experiment afforded the experimenters to track the pathways of formation for these various species.

Prebiotic species are produced in smaller concentrations within a more oxidizing environments (Miller & Urey 1959). Methane has been found to be important for the formation of prebiotic compounds (Schlesinger & Miller 1983; Miyakawa et al. 2002). The correlation between reducing chemistry and the efficient production of prebiotic molecules, combined with compelling evidence that the atmosphere of the early Earth was oxidizing (Kasting 1993), would suggest that other processes were responsible for producing the prebiotic chemical inventory on Earth. This process is hypothesized to have taken place within hydrothermal vents (e.g. Ferris 1992), on the surfaces of crystals (Vijayan 1980), or possibly within the interstellar medium (e.g. Greenberg et al. 1995).

Cleaves et al. (2008) have repeated Miller's experiment in a reducing environment, and discovered that amino acids can be efficiently produced in such environments, but that nitrites (e.g. HONO) destroy these species as quickly as they are produced. Adding ferrous iron, in the form of FeO or FeS_2 (in the form of pyrite surfaces) effectively removes the nitrites and allows the amino acids to survive.

 $^{^{10}}$ The debate is ongoing (Claire et al. 2006; Catling 2006).

¹¹http://omniweb.sci.gsfc.nasa.gov/vitmo/

We explore the formation of glycine in the context of a weak radiating source. An unattenuated monochromatic beam of light at $\lambda_0=1000$ Å is applied with an intensity of $\approx 2\times 10^{-3}$ erg cm⁻² s⁻¹, corresponding to a flux of $F_0=10^8$ photons cm⁻² s⁻¹. This flux is applied to Eq. (18) such that:

$$k_{\text{ph},i}(z) = \int_{1\text{Å}}^{10^4\text{Å}} \sigma_i(\lambda) F_0 \delta(\lambda - \lambda_0) d\lambda;$$

= $F_0 \sigma_i(\lambda_0),$ (51)

where δ is the Dirac delta function.

The formation pathways for glycine have not been rigorously determined, although there are some proposed pathways. We include four possible pathways to glycine formation in our network. First, we include glycine formation via the three body interaction of various species. These reactions have significant barriers, and so will only occur efficiently at rather high temperatures. The reactions are:

$$C_2H_4 + HNO_2 \rightarrow NH_2CH_2COOH,$$
 (52)

$$C_2H_5 + NO_2 \rightarrow NH_2CH_2COOH,$$
 (53)

$$CH_3NO + H_2CO \rightarrow NH_2CH_2COOH,$$
 (54)

with rate constants set equal to the three-body formation for analogous chemical species (e.g. CH₂COOH). Also included is the ion-neutral pathway proposed for interstellar formation for glycine from Charnley (1997),

$$CH_6NO^+ + HCOOH \rightarrow C_2H_6NO_2^+ + H_2O, (55)$$

 $C_2H_6NO_2^+ + e^- \rightarrow NH_2CH_2COOH + H.$ (56)

And finally, the formation of glycine by a possible pathway similar to that suggested by Patel et al. (2015),

$$CH_3NO + CH_3O \rightarrow NH_2CH_2COOH + H$$
 (57)

is included.

Additionally, we include FeO and reactions between FeO and nitrites. We also inject our gas with HCOOH in order to facilitate the ion-neutral formation pathway; it is likely that there are other presently unknown paths of formation for formic acid. We run this network for a set of five different initial compositions given in Table 2, labeled

Model A - E. Model A is a strongly reducing environment, with only the gases NH₃, CH₄, H₂ and H₂O, FeO and HCOOH (Model A). We transition to a more reducing environment in the successive models (Models B, C, D). Finally, for Model E, we run the experiment starting solely from CO₂, N₂, H₂O, FeO and HCOOH. We run all models using the unattenuated UV flux, at 1 bar pressure and 300 K temperature. The model is run to $t \approx 1$ week. Our results are plotted in Figure 19.

Moving from Model B to E, less and less glycine is formed, falling from a mixing ratio of 10^{-6} for Model B to 10^{-8} for Model E. This is what is expected from the Miller-Urey experiments performed for various chemical compositions: as the chemistry becomes less reducing, it becomes more difficult to form prebiotic molecules.

More interesting is Model A. If all N_2 and CO_2 are removed, certain formation pathways to NO_2 , HNO_2 and especially H_2CO are inhibited. Additionally, HCNO forms more slowly from HCN, and especially the ionic form, $CHNO^+$ (in its various permutations) is difficult to form without some excess unbonded atomic nitrogen or oxygen present in the gas. Model A produces virtually no glycine. We traced this back to the key reactions:

$$N_2 + \gamma \rightarrow N_2^+ + e^-,$$

$$N_2^+ + e^- \rightarrow N + N,$$

$$CO_2 + \gamma \rightarrow CO + O$$
(58)

the same formation pathway for amines in the early Earth as suggested by Zahnle (1986). In our case, however, the atomic nitrogen and oxygen are both important in completing the formation of HCNO and its isomers.

6. Conclusion

In this paper, we have presented a gas-phase chemical network, STAND2015. The photochemistry/diffusion code, Argo, was used to test the network. We have shown that the predictions from STAND2015 converge to chemical equilibrium under the appropriate conditions and also that the molecular diffusion modeled by Argo makes a reasonable approximation to analytical calculations of molecular diffusion for an isothermal gas in hydrostatic equilibrium. We have compared our model results (STAND2015+Argo) to

chemical kinetics models for HD209458b, Jupiter and the Earth. For Jupiter, we found that ion-neutral chemistry may provide significant alternative pathways to formation of various hydrocarbons, especially ethylene (C_2H_4) .

Finally, we numerically simulate a Urey-Millerlike experiment¹² under various initial chemistries. We found that, in an artificial environment, when derivatives of FeO and pyrite (FeS₂) can destroy nitrites in the presence of a reservoir of formic acid, the formation of glycine is considerable also in reducing environments, approaching a mixing ratio of $\sim 10^{-6}$. For an environment more similar to the atmosphere of the early Earth, the mixing ratio drops to $\sim 10^{-8}$. Surprisingly, for a gas without any CO2, O2 or N2, virtually no glycine is formed. If this result is robust for various other energy sources (shocks, thermal energy, etc.) and for other prebiotic species, this would suggest that the early Earth chemistry should not be too strongly reducing, else the formation of glycine and other prebiotic species would be severely inhibited.

This network has limitations. It has only been tested for 1D atmosphere models, with non-selfconsistent temperature profiles. Using this network within a global circulation model is presently unrealistic, but a reduced version of this network, constructed specifically for given atmospheres, could in principle be employed in 2D or 3D atmosphere simulations. Sulfur chemistry has been shown to play an important role in the formation of prebiotics, and is an essential constituent in volcano plumes. The inclusion of sulfur chemistry will be a natural next step to take the model. Additionally, the models of prebiotic chemistry should consider the formation of species other than glycine. The formation of ribose $(C_5H_{10}O_5)$ of nucleotides, such as adenine $(C_5H_5N_5)$, and of phosphorus-bearing species should also be included to more fully encapsulate the formation of the prebiotic chemical reservoir.

One serious problem with this network, and indeed with any chemical kinetics network, is the uncertainty in rate coefficients. The effects of this uncertainty can be estimated using sensitivity analysis (e.g., within Venot et al. 2012), but can ultimately only be resolved slowly as better ex-

perimental and theoretical determinations of the reaction rates are made available. More accurate determinations, especially of the reaction rates for the nitrogen chemistry, would be extremely helpful. This network and model provide a window into a detailed analysis of prebiotic chemistry, but much work must still be done in order to accurately predict the full budget of prebiotic molecules in the variety of environments in which they may occur.

Both authors gratefully acknowledge the support of the ERC Starting Grant #257431. P. B. R. is grateful to J. I. Moses for several helpful discussions about the network and model comparisons, to G. Laibe for his help with the Lagrangian numerical methods, and to C. R. Stark for his help understanding prebiotic formation in plasma environments. Both authors are grateful for the anonymous referee whose report has helped significantly improve this paper. They also express thanks to Ian Taylor at St Andrews for his help with computational resources. Finally, they acknowledge the National Institute of Standards and Technology, the databases of which were essential to the completion of this project.

 $^{^{12}}$ The experiment we simulate is more like that of Patel et al. (2015).

A. List of Species, Reactions and Rates

The purpose of this appendix is to explicitly lay out the content of the chemical network itself. We list the species considered in the network and the reactions.

The species include the elements H/C/N/O, and the network includes a complete chemistry for molecules and ions of up to 2 carbon, 6 hydrogen, 2 nitrogen and 3 oxygen atoms. The different chemical kinetics for various neutral molecular isomers is included as completely as possible, although much about branching ratios for reactions is presently not well understood. A list of all the neutral species is given in Table 4. This table lists the species considered and includes the formula as used in the network, the standard formula, the name of the molecule and the source we used for the thermochemical data. In some cases, the chemical formula in the network is different from the standard chemical formula. This is because we incorporated our own method for distinguishing isomers, in order to make sure that we did not incorporate the same molecule under two different formulas.

This list also includes some species with the elements Na, Mg, Si, Cl, K, Ti and Fe. The chemistry attempts to include only the dominant species with these elements, in which they would be present in the gas phase. These species are generally only present in the gas-phase for very high temperatures (generally > 1000 K). For cooler objects, these species are typically ignored. The noble gases He and Ar are included, both for the sake of completeness, and because they can play an important role in organic ion-neutral chemistry through charge-exchange reactions.

Ions are also included, and a list of the ionic species is given in Table 5. In this case, the uncertainty in reaction rates and branching ratios is much more severe, and so we made no attempt at present to distinguish isomers of ionic species.

It is difficult to determine which rate constants to use for a specific reaction, since there are often many to choose from, and they do not always agree well with each other. We employed the following method for determining which rate constant to include in our network, after plotting all the rate constants versus temperature over a range of 100 K to 30000 K:

- 1. If there exists only one published rate constant for a given reaction, we use that value.
- 2. Reject all rate constants that become unrealistically large at extreme temperature.
- 3. Choose rate constants that agree with each other over the range of validity.
- 4. If the most recent published rate constant disagrees with (3), and the authors give convincing arguments for why the previous rates were mistaken, we use the most recently published rate.

The full list of forward reactions and rate constants determined by this method comprise the STAND2015 network and are given in Table 6. Reverse reactions are not explicitly shown; when reactions are reversible, bidirectional arrows are shown. When they are irreversible, or simply not reversed in the network, only unidirectional arrows are shown. Table 6 additionally includes a full list of the references for the rate constants used for each given reaction.

B. Reversing Reactions

For reverse reactions, we follow the prescription given by Burcat & Ruscic (2005). For the reaction:

$$A + B \to C + D + E, \tag{B1}$$

there is a rate constant, k_f . We resolve to determine the reverse rate constant, k_r , for the reaction:

$$C + D + E \to A + B. \tag{B2}$$

Note that the number of species is different between the r.h.s. and l.h.s. of Eq. (B1). We denote this difference in number of reactants and products (n_{react} and n_{prod} , respectively) by $\Delta \nu$, which in our case $= n_{\text{prod}} - n_{\text{react}} = 2 - 3 = -1$. We then solve for the reaction rate constant as (Burcat & Ruscic 2005, their Eq. (6)),

$$K_c = (RT)^{-\Delta\nu} \exp\left(\Delta a_1 \left(\log T - 1\right) + \frac{\Delta a_2 T}{2} + \frac{\Delta a_3 T^2}{6} + \frac{\Delta a_4 T^3}{12} + \frac{\Delta a_5 T^4}{20} - \frac{\Delta a_6}{T} + \Delta a_7\right),\tag{B3}$$

where $R = 8.314472 \text{ J mol}^{-1} \text{ K}^{-1}$ is the gas constant, and $\Delta a_i = a_i(\text{C} + \text{D} + \text{E}) - a_i(\text{A} + \text{B})$ for $1 \le i \le 7$ are the NASA thermodynamics coefficients, which Burcat & Ruscic (2005) describes and tabulates. It is important to emphasize here, as done by Visscher & Moses (2011), the multiplicative factor $(RT)^{-\Delta\nu}$, which in our example would be $1.38065 \times 10^{-22} T$.

The Burcat values for the NASA coefficients have been used for all possible species (see Tab. 4. For some species, however, the coefficients had to be obtained from other sources. For sources with elements Na, Mg, Si, Cl, K, Ti and Fe, the Burcat values were sparse, so we made use instead of the NASA-CEA values (McBride et al. 1993; Gordon & McBride 1999), which use 9-coefficient polynomials, so we fit them to a series of 7-coefficient polynomials for various temperature ranges. We do the same for the monatomic gases and ions at high temperatures 6000 K < T < 20000 K, using fits to the polynomials provided by Gordon & McBride (1999). For some species, the thermodynamic properties have not been determined. In these cases, for neutral species we use Benson's additivity method as described by Cohen & Benson (1993).

Benson's additivity method can be naturally combined with the NASA and Burcat polynomial coefficients using the experimental values for the small alkanes listed within Cohen & Benson (1993). For the arbitrary alcohol from Cohen & Benson (1993), we use methanol, and for the arbitrary ether, dimethyl ether. The Benson coefficients are:

$$P_i = \frac{1}{2} a_i(C_2 H_6),$$
 (B4)

$$S_i = a_i(C_3H_8) - a_i(C_2H_6),$$
 (B5)

$$D_i = a_i(C_2H_6O) - a_i(C_2H_6),$$
 (B6)

$$F_i = a_i(\mathrm{CH_3OH}) - a_i(\mathrm{CH_4}). \tag{B7}$$

Here, $a_i(X)$ denotes the seven coefficients, i = 1, ..., 7 for species X. The coefficients for fundamental bonds are calculated using these coefficients as follows:

$$a_i([C - H]) = \frac{1}{2}P - \frac{1}{4}S,$$
 (B8)

$$a_i([C-C]) = \frac{3}{2}S - P,$$
(B9)

$$a_i([C - O]) = \frac{1}{2}D + \frac{3}{4}S - \frac{1}{2}P,$$
 (B10)

$$a_i([O - H]) = F - \frac{1}{2}D - \frac{1}{2}S.$$
 (B11)

The values for these bonds are given in Table 3. The values for [N-H], [N-C] and [N-O] are similarly determined.

It has been suggested by Lias (1988) and Cohen & Benson (1993) that using Benson's additivity method to determine the thermodynamic properties of ions, or at least strongly of strongly polarizing groups, can lead to large errors, because the thermodynamic properties of ions do not depend linearly on their length, although Hammerum & Sølling (1999) have had some success applying Benson's method to ions.

We found, by investigating the thermodynamic properties of ionic species tabulated by Burcat & Ruscic (2005), that the thermodynamic properties of ions do depend nonlinearly but predictably based on size. We therefore placed all the known thermodynamic properties of ions into a database, and have extrapolated to calculate the thermodynamic properties for the undetermined ions.

C. Outgassing, Condensation, Evaporation and Escape

Boundary conditions play a key role in determining the atmospheric compositions of planets. For rocky planets, these boundary conditions are set by outgassing and escape into the exosphere. At temperatures $\lesssim 1500$ K, metals such as silicates, iron, corundum, begin to condense out of the exoplanet and brown dwarf atmospheric gas phase. At much lower temperatures, when, various other species (e.g. water, ammonia, methane) may also condense out. It is important for comparison to previous models to consider both the atmospheric boundary conditions and atmospheric condensation.

As discussed in Section 3.1, there exist, in addition to the STAND2015 reactions, a series of "banking" reactions for all major species, that collect particles and reintroduce them to the fluid parcel at a rate determined by the diffusion time-scales. The very bottom banking reaction can be set to act effectively as an outgassing rate. Imagine a particular reservoir for a species, A. This reservoir is outgassing into the atmosphere with a flux, $\Phi(A)$ [cm⁻² s⁻¹]. This can be accounted by first taking a reservoir concentration of A, which for a large reservoir will be $\gg [A](z=0)$, the bottom of the atmosphere. For a reservoir that will not be appreciably depleted over the chemical-dynamical time-scale of the atmosphere, the rate is simply:

$$P_{\text{out}}(\mathbf{A}) = \frac{\Phi(\mathbf{A})}{\Delta z}.$$
 (C1)

For a finite reservoir, we can place the reservoir concentration into the bottom "bank" for the species in question, and the t=0 flux, $\Phi(A,0)$, and concentration ([BA]) can be used to determine the rate of outgassing,

$$P_{\text{out}}(\mathbf{A}) = L(\mathbf{B}\mathbf{A})[\mathbf{B}\mathbf{A}],\tag{C2}$$

where

$$L(BA) = \frac{\Phi(A,0)}{[BA(t=0)] \Delta z}.$$
 (C3)

These approximations are not used anywhere in this paper. For HD209458b, we simply start with solar elemental abundances, with everything in atomic form at the bottom of the atmosphere. For both Jupiter and Earth, we start with fixed lower boundary conditions.

Condensation or evaporation of species A can be treated by the reactions ("JA" represents "A in condensate form"):

$$A \to JA$$
, for condensation; (C4)

$$JA \to A$$
, for evaporation. (C5)

This physical process is treated in two ways in this paper for Earth and Jupiter. The first method is by considering supersaturation concentrations, above which the species in question condenses out and below which the species in question will evaporate. This method is given by (Hamill et al. 1977; Toon & Farlow 1981; Hu et al. 2012), and has the form (for species A):

$$P = \frac{[A]}{t_c}, \qquad L = \frac{[JA]}{t_c} \tag{C6}$$

$$t_c = \frac{m_{\rm A} v_{th}}{4\rho_{\rm nuc}} \frac{n_{\rm gas} - n_c(T, p)}{a} \tag{C7}$$

where $m_{\rm A}$ [g] is the mass of the condensing species, v_{th} is the thermal velocity of the gas, $\rho_{\rm nuc}$ [g cm⁻³] is the material density of the condensation seed, $n_{\rm gas}$ [cm⁻³] is the density of the gas, and n_c [cm⁻³] is the saturation number density, at the given temperature and pressure, and a [cm] is the average radius of the nucleation site. We consider condensation only for low temperatures, so $n_c = p_v/k_BT$, where p_v [dyn cm⁻²] is the vapor pressure, and is estimated using the relatively simple Antoine equation:

$$\log p_v = A - \frac{B}{C+T},\tag{C8}$$

where A, B and C are all parameters taken from the tabulated NIST chemistry webbook¹³.

Alternatively, one can use the method commonly used in the astrochemical context (Hasegawa et al. 1992; Caselli et al. 1998), where

$$L\left[\mathbf{s}^{-1}\right] = \pi a^2 v_{th} n_{\text{nuc}} \tag{C9}$$

and

$$P = \nu_0[JA] e^{-E_D/k_B T}.$$
 (C10)

Here, E_D is the desorption energy, an empirically determined quantity, taken from Garrod et al. (2008). The frequency,

$$\nu_0 [\text{Hz}] = \left(\frac{2n_s E_D}{\pi^2 m_A}\right)^{1/2},$$
 (C11)

is the characteristic frequency of the surface. The number of sites is estimated, also empirically, by the relation $n_s = 1.5 \times 10^{15} \, \mathrm{cm}^2 \, \left(a/a_0\right)^2$, where $a_0 = 0.1 \, \mu\mathrm{m}$. The advantage of this approximation is that it is identical to the form generally used for complex surface chemistry in protoplanetary disks. This would allow one to take the results from disk chemistry and utilize them straightforwardly in atmospheric outgassing models.

It is worth pointing out that exponentiating Eq. (C8), dividing by k_BT , and then placing the resulting form of n_c into Eq. (C7), yields a form:

$$\frac{P}{L} \sim \frac{\text{Const.}}{v_{th}} e^{T_c/T}$$
 (C12)

where $T_c/T = B/(C+T)$ from Eq. (C8). The two forms are therefore analogous parameterizations, with the same temperature dependence, but the saturation approach is dependent on the parameterized vapor pressure, and the deposition approach is parameterized by the number of nucleation sites and the binding energy of the nucleation particle.

Neither the supersaturation method nor the deposition method explain where the condensation seeds first arise. It is assumed that the condensation seeds are already present, and therefore that condensation occurs whenever the supersaturation ratio, $S \gtrsim 1$. In some environments like Earth, the condensation seeds come in the form of sand or ash particles, and the supersaturation ratio for water to condense is very small, $S \approx 1.01$. If the seed particles are not already present in the atmosphere, they must form within the gas phase by the growth from small to large, complex clusters. This requires a supersaturation ratio $S \gg 100$, which only occurs when $T \ll T_c$ (Helling & Fomins 2013). Zsom et al. (2012) explore the microphysics of water condensation and cloud formation for Earth and Earth-like planets

None of these reactions appear in the generic kinetic network, because their inclusion is atmosphere dependent. Condensation is not considered at all for HD209458b because it is too hot, but is considered for Earth and Jupiter for water. Ammonia and methane condensation can also be considered for Jupiter and methane and other condensation should be considered for even colder planets, such as Uranus and Neptune.

¹³http://webbook.nist.gov/chemistry/

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Table 2: I	Mixing 1	Ratios f	4 0.04 0.04 0.04 0.04 2 0.02 0.04 0.06 0.06			
Model	H_2O	CH_4	NH_3	H_2	CO_2	N_2
A	0.80	0.08	0.08	0.04	0.0	0.0
В	0.80	0.06	0.06	0.04	0.02	0.02
С	0.80	0.04	0.04	0.04	0.04	0.04
D	0.80	0.02	0.02	0.04	0.06	0.06
E	0.84	0.00	0.00	0.00	0.08	0.08

^{*} Not including the injected FeO and HCOOH

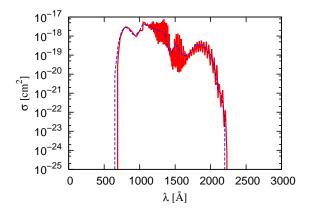


Fig. 1.— The photodissociation cross sections of $\mathrm{NH_3} \to {}^1\mathrm{NH} + \mathrm{H_2}, \, \sigma \, [\mathrm{cm^2}], \, \mathrm{as} \, \mathrm{a} \, \mathrm{function} \, \mathrm{of} \, \mathrm{wavelength}, \, \lambda \, (\mathring{\mathrm{A}}), \, \mathrm{from} \, \, \mathrm{PHIDRATES} \, \, \mathrm{(original \, data} \, \mathrm{from} \, \, \mathrm{McNesby} \, \mathrm{et} \, \mathrm{al.} \, \, 1962; \, \mathrm{Schurath} \, \mathrm{et} \, \mathrm{al.} \, \, 1969, \, \mathrm{red} \, \, \mathrm{line}).$ The data is compared to our binned fit (blue line).

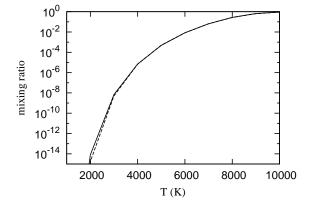


Fig. 3.— Mixing ratio as a function of temperature. The solid line is from the Saha equation and the dashed line is the result from our model calculation.

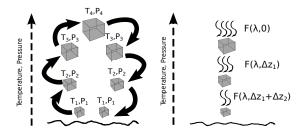


Fig. 4.— Picture representation of the model. The picture on the left represents the motion of the single parcel from the bottom of the atmosphere, T_1, P_1 , up to the top of the atmosphere, T_4, P_4 , and then back down, see Section 3.1. Once this journey is completed, we irradiate the atmosphere, by stacking up the parcel at different times, when it was located at different parts of the atmosphere. The picture on the right represents the calculation of the depth-dependent actinic flux discussed in Section 3.2. Only photons of wavelength between 1-10000 Å are considered Figure 5 gives a flowchart for the calculation.

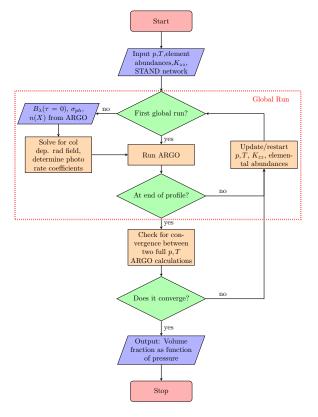


Fig. 5.— A flow-chart representation for the program.

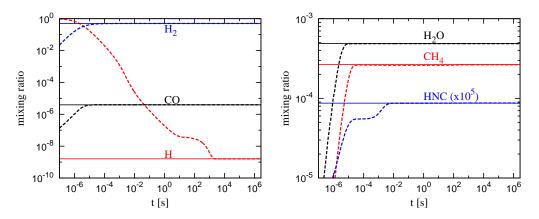


Fig. 2.— Mixing ratios as a function of time [s] at 1 bar and 1000 K (dashed lines), compared to chemical equilibrium (solid lines) for H_2 , H, CO, CH_4 and H_2O .

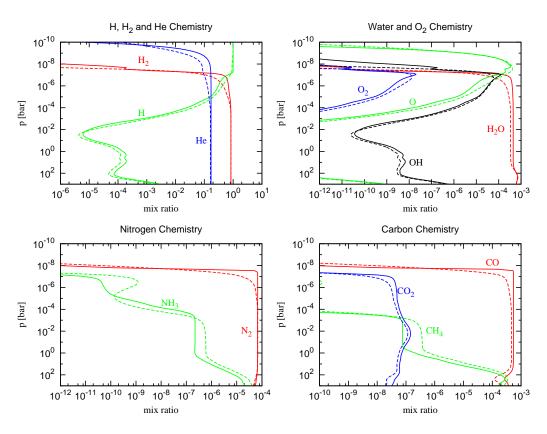


Fig. 9.— Mixing ratios for various chemical species as a function of pressure, p [bar]. A comparison between our model (solid lines) and that of Moses et al. (2011, dashed lines), for H/H₂ chemistry, water and O₂ chemistry, nitrogen chemistry and carbon chemistry in the atmosphere of HD209458b.

Table 1: Initial Conditions for the Chemistry at the Lower Boundary in terms of $n(X)/n_{\rm gas}$

Species	$\mathrm{HD209458b^a}$	Earth ^b	Early Earth ^c	Jupiter ^d
Н	9.2092(-1)			
He	7.8383(-2)			1.3600(-1)
$^{\mathrm{C}}$	2.4787(-4)			
N	6.2262(-5)			
O	4.5105(-4)			
Ar	2.3133(-6)		9.1150(-3)	
K	9.8766(-8)			
Cl	2.9122(-7)			
Fe	2.9122(-5)			
Mg	3.6663(-5)			
Na	1.6004(-6)			
Si	2.9800(-5)			
${ m Ti}$	8.2077(-8)			
CO		1.1300(-7)	4.9005(-5)	8.0000(-10)
H_2		1.0000(-6)	9.8010(-4)	8.6219(-1)
N_2		7.9172(-1)	7.8408(-1)	
NO		2.4000(-11)		
O_2		1.9793(-1)		
CO_2		3.5000(-4)	1.9602(-1)	
H_2O		1.0000(-2)	9.8010(-3)	
N_2O		3.0200(-7)		
NH_3		2.4000(-10)		
CH_4		1.9390(-6)		1.8100(-3)

 $[^]a$ Solar metallicity, from Asplund et al. (2009).

Table 3: Bond Constants for Benson Additivity

Species	a_1	a_2	a_3	a_4	a_5	a_6	a_7
С–Н							
300-1000K	1.1E0	-3.0E-3	1.2E-5	5.8E-8	4.8E-12	-2.5E3	-2.5E-2
$1000-6000 { m K}$	4.0E-1	2.3E-3	-1.9E-6	1.4E-10	-8.3E-15	-2.0E3	2.8E0
C-C							
300-1000K	-2.4E0	1.3E-3	-1.4E-5	-2.8E-7	-5.0E-13	3.0E3	3.0E0
$1000-6000 { m K}$	1.8E0	1.5E-3	5.7E-7	4.0E-11	-2.5E-15	2.5E2	-1.8E1
C-O							
300-1000K	-6.8E-1	8.3E-3	-1.0E-5	-2.0E-7	-2.3E-12	9.0E2	4.8E-1
$1000-6000 { m K}$	1.7E0	1.3E-3	8.3E-6	5.5E-11	-3.8E-15	-6.5E2	-1.1E1
О-Н							
300-1000K	5.0E-2	-7.3E-3	1.8E-5	1.2E-7	8.5E-12	-9.0E3	-4.2E0
$1000-6000 \mathrm{K}$	-4.5E-1	-3.1E-3	-6.7E-6	-1.6E10	-5.4E-14	-7.5E3	5.2E0

 $[^]b$ Surface mixing ratios based on the US Standard Atmosphere 1976.

 $^{^{}c}\,\mathrm{Based}$ on Early Earth models (Kasting 1993).

 $[^]d$ Moses et al. (2005).

 $\begin{tabular}{ll} Table 4 \\ Neutral Species included in the Stand2015 Network \\ \end{tabular}$

Network Formula	Standard Formula	Name	Thermochem Data
Н	Н	Atomic hydrogen	Burcat
$^{\mathrm{C}}$	C	Atomic carbon	Burcat
$C(^{1}D)$	$C(^{1}D)$	Singlet D carbon	Burcat
$C(^1S)$	$C(^1S)$	Singlet S carbon	Burcat
N	N	Atomic nitrogen	Burcat
O	O	Atomic oxygen	Burcat
$O(^{1}D)$	$O(^{1}D)$	Singlet D oxygen	Burcat
$O(^1S)$	$O(^1S)$	Singlet S oxygen	Burcat
He	He	Helium	Burcat
Na	Na	Atomic sodium	Burcat
${ m Mg}$	${ m Mg}$	Atomic magnesium	Burcat
Si	Si	Atomic silicon	Burcat
Cl	Cl	Atomic chlorine	Burcat
Ar	Ar	Argon	Burcat
K	K	Atomic potassium	Burcat
${ m Ti}$	${ m Ti}$	Atomic titanium	Burcat
Fe	Fe	Atomic iron	Burcat
H_2	H_2	Molecular hydrogen	Burcat
C_2	C_2	Dicarbon	Burcat
N_2	N_2	Molecular nitrogen	Burcat
O_2	O_2	Molecular oxygen	Burcat
$O_2(a^1\Delta)$	$O_2(a^1\Delta)$	Singlet oxygen	Burcat
ĊН	СН	Methylidyne radical	Burcat
$_{ m HN}$	NH	Nitrogen monohydride	Burcat
$HN(a^1\Delta)$	$NH(a^1\Delta)$	Singlet nitrogen monohydride	Burcat
ĤO	ÒН	Hydroxyl radical	Burcat
CN	$_{ m CN}$	Cyano radical	Burcat
CO	CO	Carbon monoxide	Burcat
KH	KH	Potassium hydride	Burcat
NO	NO	Nitric oxide	Burcat
HCl	HCl	Hydrogen chloride	Burcat
NaH	NaH	Sodium hydride	Burcat
MgO	$_{ m MgO}$	Magnesium oxide	Burcat
SiH	SiH	Silylidyne	NASA-CEA
SiO	SiO	Silicon monoxide	NASA-CEA
KCl	KCl	Potassium chloride	Burcat
TiO	TiO	Titanium(II) oxide	NASA-CEA
FeO	FeO	Iron(II) oxide	Burcat
O_3	O_3	Ozone	Burcat
$^3\mathrm{CH}_2$	$\mathrm{CH}_2(\mathrm{X}^3\mathrm{B}_1)$	Triplet methylene	Burcat
$^{1}\mathrm{CH}_{2}$	$\mathrm{CH}_2(\mathrm{a}^1\mathrm{A}_1)$	Singlet methylene	Burcat

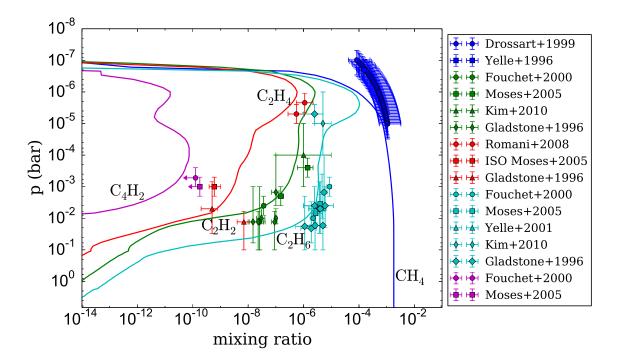


Fig. 12.— Mixing ratios for various chemical species as a function of pressure, p [bar]. A comparison between our model (solid lines) and that of various observations, for complex hydrocarbons in the stratosphere of Jupiter.

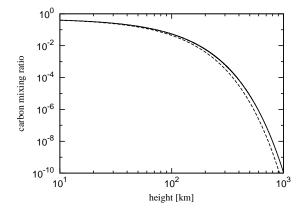


Fig. 6.— The carbon mixing ratio as a function of atmospheric height [km]. We test for diffusion, with chemistry turned off, for carbon atoms and hydrogen atoms in a gas at hydrostatic equilibrium for an isothermal gas $(g = 10^3 \text{ cm s}^{-2}, T = 300 \text{ K})$. The solid line is the result from Argo and the dashed line is the analytic result (Eq. (28)).

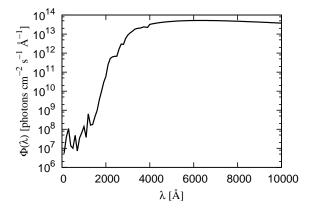


Fig. 7.— The solar flux used in our model [photons cm⁻² s⁻¹ Å⁻¹], as a function of wavelength, λ [Å], taken from Huebner & Carpenter (1979); Huebner et al. (1992); Huebner & Mukherjee (2015). Weighted versions of this flux are used for HD209458b and Jupiter. This flux is used, unadjusted, for the early Earth.

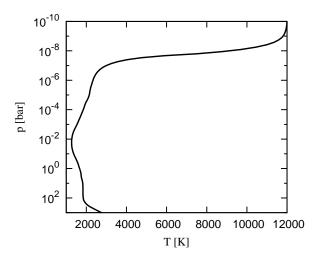


Fig. 8.— Temperature profile for HD209458b, T [K] as a function of p [bar], as used by Moses et al. (2011).

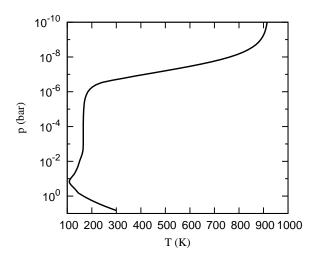


Fig. 11.— Temperature profile for Jupiter, T [K] as a function of p [bar] (Moses et al. 2005).

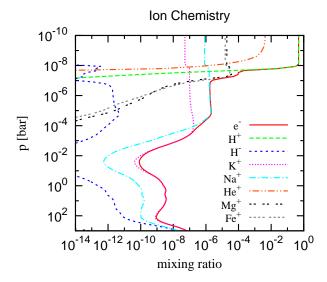


Fig. 10.— Mixing ratios for the dominant ionic species as a function of pressure, p [bar] for the atmosphere of HD209458b.

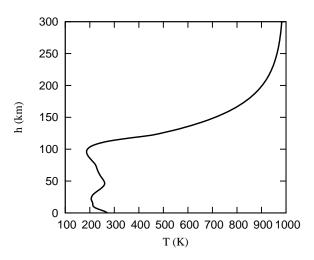


Fig. 13.— Temperature profile used for the Early Earth chemistry, temperature [K] vs. height [km]. This profile is a synthetic profile for the Earth's atmosphere generated with the MSIS-E-90 model for the date 2000/1/1 (Hedin 1987, 1991).

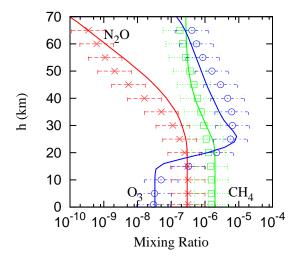


Fig. 14.— Mixing ratios of ozone, methane and nitrous oxide as a function of atmospheric height [km] for the atmosphere of the present-day Earth. The lines are produced by our model and the points are taken from globally averaged measurements (Massie & Hunten 1981). Errors are set to an order of magnitude to account for diurnal and latitudinal variations.

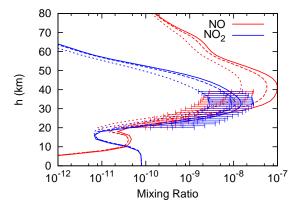


Fig. 15.— Mixing ratios of NO and NO_2 as a function of atmospheric height [km]for the atmosphere of the present-day Earth. The lines are produced by our model and the points are taken from balloon measurements (Sen et al. 1998). Errors are set to an order of magnitude to account for diurnal and latitudinal variations. We also show the results from suppressing the rate constant for Reaction 1300 in the network by a factor of 2 (dashed) and a factor of 10 (dotted).

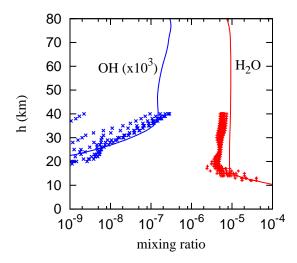


Fig. 16.— Mixing ratios of OH and $\rm H_2O$ as a function of atmospheric height [km] for the atmosphere of the present-day Earth. The lines are produced by our model and the points are taken from balloon measurements at various latitudes, heights, and times (Kovalenko et al. 2007).

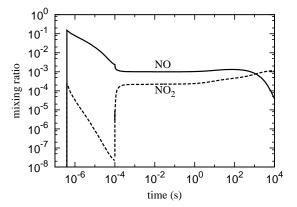


Fig. 17.— Mixing ratios of NO (solid) and NO₂ (dashed) vs time [s] in a simulation of a lightning shock on a parcel of gas with an Earth-like atmospheric composition, initially at 300 K and 1 bar. The temperature and pressure vary as a function of time as described by Orville (1968), until 10^{-4} s, at which time conditions are returned to 300 K and 1 bar, and the system is allowed to further evolve.

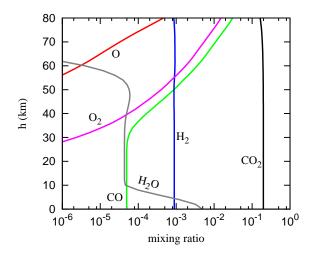


Fig. 18.— Mixing ratios for O, H₂, CO, O₂, H₂O and CO₂, as a function of height [km], for early Earth photochemistry. These results can be compared to the results of Kasting (1993, his Fig. 1).

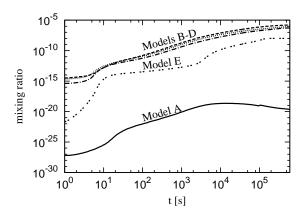


Fig. 19.— Mixing ratio of glycine as a function of time, for five lab simulations, labelled Models A-E, with parameters given in Table 2 and described in Section 5.

Table 4—Continued

TABLE 4—Continuea							
Network Formula	Standard Formula	Name	Thermochem Data				
$^{1}\mathrm{CH}_{2}$	$\mathrm{CH}_2(\mathrm{a}^1\mathrm{A}_1)$	Singlet methylene	Burcat				
C_2H	CCH	Ethynyl radical	Burcat				
$\mathrm{H_2N}$	NH_2	Amidogen	Burcat				
HN_2	$\mathrm{N}_{2}\mathrm{H}$	Amino radical	Burcat				
$\mathrm{H}_2\mathrm{O}$	$\mathrm{H}_2\mathrm{O}$	Water	Burcat				
HO_2	HO_2	Hydroperoxyl	Burcat				
C_2N	CCN	Cyano-methylidyne	Burcat				
CNC	CNC	CNC radical	Burcat				
CN_2	CNN	CNN radical	Burcat				
C_2O	C_2O	Dicarbon monoxide	Burcat				
CO_2	CO_2	Carbon dioxide	Burcat				
N_2O	N_2O	Nitrous oxide	Burcat				
NO_2	NO_2	Nitrogen dioxide	Burcat				
HCN	HCN	Hydrogen cyanide	Burcat				
HNC	HNC	Hydrogen isocyanide	Burcat				
HNO	HNO	Nitroxyl	Burcat				
NCO	NCO	Isocyanato radical	Burcat				
NaOH	NaOH	Sodium hydroxide	Burcat				
MgHO	MgOH	Magnesium monohydroxide	NASA-CEA				
NaCl	NaCl	Sodium chloride	Burcat				
SiH_2	SiH_2	Silylene	NASA-CEA				
KOH	КОН	Potassium hydroxide	Burcat				
FeO_2	FeO_2	Iron oxide	Burcat				
CH_3	CH_3	Methyl radical	Burcat				
C_2H_2	C_2H_2	Acetylene	Burcat				
$\mathrm{H_{3}N}$	NH_3	Ammonia	Burcat				
$\mathrm{H_2N_2}$	N_2H_2	Diimide	Burcat				
HNNH	HNNH	(Z)-Diazene	Burcat				
$\mathrm{H_2O_2}$	$\mathrm{H_2O_2}$	Hydrogen peroxide	Burcat				
NCCN	$(CN)_2$	Cyanogen	Burcat				
H_2CN	H_2CN	Dihydrogen cyanide	Burcat				
HCCN	HCCN	HCCN radical	Burcat				
CHN_2	HCNN	HCNN	Burcat				
$\mathrm{CH_{2}O}$	$\mathrm{H}_{2}\mathrm{CO}$	Formaldehyde	Burcat				
HOCH	НСОН	Hydroxymethylene	Burcat				
HCCO	HCCO	Ethynyloxy radical	Burcat				
COOH	СООН	Hydrocarboxyl radical	Burcat				
NH_2O	NHOH	NHOH	Burcat				
HNO_2	HNO_2	Nitrous acid	Burcat				
OCCN	NCCO	NCCO	Burcat				
OCCIV	NCCO	NCCO	Durcat				

Table 4—Continued

TABLE 4—Continuea								
Network Formula	Standard Formula	Name	Thermochem Data					
HNCO	HNCO	Isocyanic acid	Burcat					
CHNO	CHNO	Cyanic acid	Burcat					
HCNO	HCNO	HCNO	Burcat					
SiH_3	SiH_3	Silyl radical	Burcat					
CH_4	CH_4	Methane	Burcat					
C_2H_3	C_2H_3	Vinyl radical	Burcat					
$\mathrm{NH_{2}NH}$	$\mathrm{NH_{2}NH}$	Hydrazinyl radical	Burcat					
N_2O_3	N_2O_3	Nitrogen trioxide	Burcat					
$\mathrm{CH_{3}N}$	$\mathrm{CH_{2}NH}$	Methanimine	Burcat					
$\mathrm{CH_{2}CN}$	$\mathrm{CH_{2}CN}$	Cyanomethyl radical	Burcat					
$\mathrm{CH_2N_2}$	$\mathrm{CH_{2}N_{2}}$	Diazomethane	Burcat					
HC_3N		Propiolonitrile*	Burcat					
$\mathrm{CH_{2}OH}$	$\mathrm{CH_{2}OH}$	Hydroxymethyl radical	Burcat					
$\mathrm{CH_{3}O}$	$\mathrm{CH_{3}O}$	Methoxy radical	Burcat					
C_2H_2O	$\mathrm{H}_{2}\mathrm{CCO}$	Ethenone	Burcat					
HCOOH	HCOOH	Formic acid	Burcat					
$\mathrm{CH_2O_2}$	$\mathrm{CH_{2}OO}$	CH2OO	Burcat					
HNO_3	HNO_3	Nitric acid	Burcat					
$\mathrm{NH_{2}OH}$	$\mathrm{NH_{2}OH}$	Hydroxylamine	Burcat					
HCOCN	HCOCN	HCOCN	Benson					
${\rm MgO_2H_2}$	$\mathrm{H_2MgO_2}$	Magnesium hydroxide	NASA-CEA					
SiH_4	SiH_4	Silane	Burcat					
C_2H_4	C_2H_4	Ethylene	Burcat					
C_3H_3		Propargyl radical*	Burcat					
$\mathrm{H_4N_2}$	$\mathrm{N_{2}H_{4}}$	Hydrazine	Burcat					
$\mathrm{H_4O_2}$	$H_2O \cdot H_2O$	Water dimer	Burcat					
$\mathrm{CH_{3}CN}$	$\mathrm{CH_{3}CN}$	Acetonitrile	Burcat					
C_2H_3N	$\mathrm{CH_{2}CNH}$	CH2=C=NH	Burcat					
$\mathrm{CH_{3}N_{2}H}$	$\mathrm{CH_{3}N_{2}H}$	Methyl diazene	Burcat					
$\mathrm{CH_{3}OH}$	$\mathrm{CH_{3}OH}$	Methanol	Burcat					
$\mathrm{CH_{3}O_{2}}$	$\mathrm{CH_{3}O_{2}}$	CH3O2	Burcat					
C_2H_3O	$\mathrm{CH_{3}CO}$	Acetyl radical	Burcat					
$\text{cyc-C}_2\text{H}_3\text{O}$	Oxyranyl	Oxiranyl radical	Burcat					
$\mathrm{CH_{2}CHO}$	$\mathrm{CH_{2}CHO}$	CH2CHO	Burcat					
C_3H_2O		2-Propynal*	Benson					
$C_2H_2O_2$	$(CHO)_2$	Glyoxal	Burcat					
H_2NNO_2	$ m H_2N-NO_2$	H2N-NO2	Burcat					
$\mathrm{CH_{3}NO}$	$HCONH_2$	Formamide	Burcat					
C_2H_5	C_2H_5	Ethyl radical	Burcat					
C_3H_4		Propyne*	Burcat					
$\mathrm{CH_{5}N}$	$\mathrm{CH_{3}NH_{2}}$	Methylamine	Burcat					

Table 4—Continued

Network Formula	Standard Formula	Name	Thermochem Data
C_3H_3N	• • •	Acrylonitrile*	Burcat
C_2H_4O	$\mathrm{CH_{3}CHO}$	Acetaldehyde	Burcat
H_2C_2HOH	$\mathrm{CH_{2}CHOH}$	Vinyl alcohol	Burcat
Oxirane	Oxirane	Oxirane	Burcat
C_3H_3O		1-Oxoprop-2-3nyl*	Burcat
$\mathrm{CH_4O_2}$	$\mathrm{CH_{3}OOH}$	Methyl peroxide	Burcat
$\mathrm{CH_{3}OCO}$	$\mathrm{CH_{3}OCO}$	$\mathrm{CH3OC}(\cdot)(\mathrm{O})$	Burcat
$\mathrm{CH_{3}NO_{2}}$	$\mathrm{CH_{3}NO_{2}}$	Nitromethane	Burcat
$\mathrm{CH_{3}ONO}$	$\mathrm{CH_{3}ONO}$	Methyl nitrite	Burcat
C_2H_6	C_2H_6	Ethane	Burcat
C_4H_4		1-Buten-3-yne*	Burcat
$\mathrm{CH_{2}NCH_{3}}$	NH_2NCH_3	N-Methyl methanimine	Benson
CH_3COOH	CH_3COOH	Acetic acid	Burcat
CH_3OCHO	$CHOOCH_3$	Methyl formate	Burcat
CH_3CHOH	CH_3CHOH	1-hydroxy Ethyl radical	Burcat
$\mathrm{CH_{3}CH_{2}O}$	$\mathrm{CH_{3}CH_{2}O}$	Ethoxy radical	Burcat
$\mathrm{CH_{3}OCH_{2}}$	$\mathrm{CH_{3}OCH_{2}}$	Methoxymethyl radical	Burcat
$\mathrm{CH_{3}NO_{3}}$	$\mathrm{CH_{3}NO_{3}}$	Methyl nitrate	Burcat
$C_2H_3NO_2$	$C_2H_3NO_2$	Nitroethylene	Burcat
$\mathrm{Si}_{2}\mathrm{H}_{6}$	$\mathrm{Si}_{2}\mathrm{H}_{6}$	Disilane	Burcat
C_3H_6		Propene*	Burcat
C_2H_6N	$(CH_3)_2N$	Dimethyl amidogen	Burcat
C_2H_5OH	$\mathrm{CH_{3}CH_{2}OH}$	Ethanol	Burcat
C_2H_5OO	C_2H_5OO	C2H5OO	Burcat
$C_2H_4O_3$	$HOCH_2COOH$	Glycolic acid	Burcat
$(CH_3)_2O$	$(CH_3)_2O$	Dimethyl ether	Burcat
C_2H_5NO	C_2H_5NO	Acetaldoxime	Benson
C_4H_6	• • •	1,3-Butadiene*	Burcat
$(CH_3N)_2$	$(CH_3N)_2$	Dimethyl diazene	Burcat
$(CH_3O)_2$	$(CH_3O)_2$	Dimethyl peroxide	Burcat
$(CH_2OH)_2$	$(CH_2OH)_2$	1,2-Ethanediol	Burcat
$(CH_3)_2CO$	$(CH_3)_2CO$	Acetone	Burcat
$C_2H_6O_2$	$HOCH_2CH_2OH$	Ethylene glycol	Burcat
$C_2H_5NO_2$	NH_2CH_2COOH	Glycine	Burcat
aC2H5NO2	$C_2H_5NO_2$	Nitroethane	Burcat
bC2H5NO2	C_2H_5ONO	Ethyl nitrate	Benson
C_3H_8	• • •	Propane*	Burcat
$(\mathrm{CH_3})_2\mathrm{N_2O}$	$(CH_3)_2N_2O$	Dimethylnitrosamine	Benson
C_4H_{10}	• • •	Butane*	Burcat

Table 5: List of ions included the Stand 2015 Net-

work						
e-	C^{+}	C-	H^{+}	H-	K^{+}	N^+
O_{+}	$O^{+}(^{2}D)$	$O^{+}(^{3}P)$	O_{-}	Ar^{+}	Cl^+	C_2^+
C_2^-	C_3^+	C_4^+	CH^{+}	CN^+	CN^-	CO_{+}
$\mathrm{Fe^{+}}$	H_2^+	H_3^+	HN^+	HO^{+}	HO^-	$\mathrm{He^{+}}$
Mg^{+}	Na^{+}	N_2^+	N_3^+	N_3^-	NO^{+}	NO-
O_2^+	$O_2^+(X^2\Pi_g)$	O_2^-	O_3^-	Si ⁺	Ti^+	Ar_2^+
ArH^+	C_2H^+	C_2H^-	C_2N^+	C_2O^+	C_3H^+	C_3N^+
C_3O^+	C_4H^+	C_5N^+	CH_2^+	CH_3^+	CH_4^+	CH_5^+
CHN^+	CHO^+	CN_2^+	CNO^+	CNO^-	CO_2^+	CO_3^-
CO_4^+	CO_4^-	FeO^+	$\mathrm{H_2N^+}$	$\mathrm{H_2N^-}$	$\mathrm{H_2O}^+$	$\mathrm{H_{3}N^{+}}$
$\mathrm{H_{3}O^{+}}$	$\mathrm{H_4N^+}$	HN_2^+	HN_3^+	HNO^{+}	HO_2^+	HO_2^-
HO_4^+	HSi^+	He_2^+	$\mathrm{HeH^{+}}$	${\rm MgO^+}$	N_2O^+	NO_2^+
NO_{2}^{-}	NO_{3}^{-}	$\mathrm{Si}_2^{ar{+}}$	SiH ⁺	SiO^+	TiO^+	Ar_2H^+
ArH_3^+	$C_2H_2^+$	$C_2H_2^-$	$C_2H_3^+$	$C_2H_3^-$	$C_2H_4^+$	$C_2H_5^+$
$C_2H_6^+$	$\mathrm{C_2H}_7^+$	C_2HN^+	C_2HO^+	C_2HO^-	$C_2N_2^+$	$C_3H_2^+$
$C_3H_3^+$	$C_3H_4^+$	$\mathrm{C_3H}_5^+$	$\mathrm{C_3H_6^+}$	$\mathrm{C_3H}_7^+$	$\mathrm{C_3H_8^+}$	$C_3H_9^+$
C_3HN^+	$C_3N_2^+$	$C_3N_3^+$	$C_4H_2^+$	$C_4H_3^+$	$C_4H_4^+$	$C_4H_5^+$
$\mathrm{C_4H_7^+}$	$C_4H_8^+$	$C_4H_9^+$	C_5HN^+	$\mathrm{CH_2N^+}$	$\mathrm{CH_2O^+}$	$\mathrm{CH_{3}N^{+}}$
$\mathrm{CH_{3}O^{+}}$	$\mathrm{CH_{3}O^{-}}$	$\mathrm{CH_4N^+}$	$\mathrm{CH_4N^-}$	$\mathrm{CH_4O^+}$	$\mathrm{CH_5N^+}$	$\mathrm{CH_{5}O^{+}}$
$\mathrm{CH_6N^+}$	CHNO ⁺	CHO_2^+	CHO_2^-	FeO_2^+	H_2NO^+	$\mathrm{H_2O}_2^+$
$H_3O_2^+$	$\mathrm{HN_2O^+}$	$HNO_2^{\overline{+}}$	$MgHO^+$	MgO_2^+	$\mathrm{Si}_{2}\mathrm{H}^{+}$	SiCH ⁺
SiH_2^+	SiH_3^+	SiH_3^-	SiH_4^+	SiH_5^+	SiHO ⁺	$C_2H_2N^+$
$C_2H_2N^-$	$C_2H_2O^+$	$C_2H_3N^+$	$C_2H_3O^+$	$C_2H_3O^-$	$C_2H_4N^+$	$C_2H_4O^+$
$C_2H_5N^+$	$C_2H_5O^+$	$C_2H_5O^-$	$C_2H_6O^+$	$C_2H_7O^+$	$C_2HN_2^+$	$C_3H_2N^+$
$C_3H_4O^+$	$C_3H_5O^+$	$C_3H_6N^+$	$C_3H_6O^+$	$C_3H_7O^+$	$C_3H_9O^+$	$C_3HN_2^+$
$C_4H_2N^+$	$\mathrm{CH_2NO}^+$	$\mathrm{CH_{3}NO^{+}}$	$\mathrm{CH_4NO^+}$	$\mathrm{CH_{5}NO^{+}}$	$\mathrm{CH_6NO^+}$	$\mathrm{CH_2O}_2^+$
$\mathrm{CH_{2}OH^{+}}$	$\mathrm{CH_3O_2^+}$	$\mathrm{H_2NO}_2^+$	$H_2NO_3^+$	$\mathrm{Si}_{2}\mathrm{H}_{2}^{+}$	$\mathrm{Si}_{2}\mathrm{H}_{3}^{+}$	$\mathrm{Si}_{2}\mathrm{H}_{4}^{+}$
$\mathrm{Si}_{2}\mathrm{H}_{5}^{+}$	$\mathrm{Si}_{3}\mathrm{H}_{2}^{+}$	$\mathrm{Si}_{3}\mathrm{H}_{3}^{+}$	$\mathrm{Si}_{3}\mathrm{H}_{4}^{+}$	$\mathrm{Si}_{3}\mathrm{H}_{5}^{+}$	$\mathrm{Si}_{3}\mathrm{H}_{6}^{+}$	$\mathrm{Si}_{3}\mathrm{H}_{7}^{+}$
$\mathrm{Si}_4\mathrm{H}_2^+$	$\mathrm{Si}_4\mathrm{H}_3^+$	$\mathrm{Si}_{4}\mathrm{H}_{4}^{+}$	$\mathrm{Si}_{4}\mathrm{H}_{5}^{+}$	$\mathrm{Si}_{4}\mathrm{H}_{6}^{+}$	$\mathrm{Si}_4\mathrm{H}_7^+$	$SiCH_2^+$
$SiCH_3^+$	$SiCH_4^+$	$SiCH_5^+$	SiC_2H^+	SiH_3O^+	SiH_3O^-	aCHNO ⁺
$C_2H_4NO^-$	$C_2H_5O_2^+$	$C_4H_7O_2^+$	$\mathrm{CH_2NO_2^-}$	$\mathrm{CH_3NO}_2^+$	$\mathrm{CH_4NO}_2^+$	$MgH_2O_2^+$
$\operatorname{SiC}_{2}\operatorname{H}_{3}^{+}$	$SiC_2H_4^+$	$SiC_2H_5^+$	$SiC_2H_6^+$	$\mathrm{TiC}_{2}\mathrm{H}_{4}^{+}$		

 ${\it TABLE~6} \\ {\it STAND2015~CHEMICAL~KINETICS~NETWORK}$

#	Type	Reaction	α	β	γ	Ref
1	2d	$C_2 \leftrightharpoons C + C$	2.49e-08	0.00	71600	1
2	2d	$C_2 \leftrightharpoons C + C$	6.01e + 11	-1.00	71600	
3	2d	$CH \leftrightharpoons C + H$	3.16e-10	0.00	33700	2
4	2d	$CH \leftrightharpoons C + H$	7.63e + 09	-1.00	33700	
5	2d	$CN \leftrightharpoons C + N$	1.00e-09	0.00	71000	3
6	2d	$CN \leftrightharpoons C + N$	2.42e + 10	0.00	71000	
7	2d	CO = C + O	1.52e-04	-3.10	129000	4
8	2d	CO = C + O	3.67e + 15	-4.10	129000	
9	2d	$H + H \leftrightharpoons H_2$	9.13e-33	-0.60	0	30
10	2d	$H + H \leftrightharpoons H_2$	1.00e-11	0.00	0	5
11	2d	$HN \leftrightharpoons H + N$	2.99e-10	0.00	37700	6
12	2d	$HN \leftrightharpoons H + N$	7.22e + 09	-1.00	37700	
13	2d	$H + O \leftrightharpoons HO$	4.33e-32	-1.00	0	7
14	2d	$H + O \leftrightharpoons HO$	1.05e-12	-2.00	0	
15	2d	$N_2 \leftrightharpoons N + N$	8.86e-05	-3.33	113000	8
16	2d	$N_2 \leftrightharpoons N + N$	2.14e + 15	-4.33	113000	
17	2d	$NO \leftrightharpoons N + O$	4.98e-10	0.00	76600	9
18	2d	$NO \leftrightharpoons N + O$	1.20e + 10	-1.00	76600	
19	2d	$O_2 = O + O$	5.65e-10	0.00	55700	10
20	2d	$O_2 \leftrightharpoons O + O$	1.36e + 10	-1.00	55700	
21	2d	$O_2 + O \leftrightharpoons O_3$	6.00e-34	-2.40	0	169
22	2d	$O_2 + O \leftrightharpoons O_3$	2.81e-12	0.00	0	11
23	2d	$C_2H \leftrightharpoons C_2 + H$	5.00e-01	-5.16	57400	1
24	2d	$C_2H \leftrightharpoons C_2 + H$	1.21e + 18	-6.16	57400	
25	2d	$CNC \leftrightharpoons C_2 + N$	5.00e-01	-5.16	57400	Est
26	2d	$CNC \leftrightharpoons C_2 + N$	$1.21e{+18}$	-6.16	57400	
27	2d	$C_2O \leftrightharpoons C_2 + O$	5.00e-01	-5.16	57400	Est
28	2d	$C_2O \leftrightharpoons C_2 + O$	1.21e + 18	-6.16	57400	
29	2d	$CH_2 \leftrightharpoons CH + H$	9.33e-09	0.00	45100	12
30	2d	$CH_2 \leftrightharpoons CH + H$	$2.25e{+}11$	-1.00	45100	
31	2d	$C + H_2 \leftrightharpoons CH_2$	7.00e-32	0.00	0	13
32	2d	$C + H_2 \leftrightharpoons CH_2$	1.70e-11	0.00	57	
33	2d	$HCN \leftrightharpoons HNC$	1.45 e - 06	1.00	23800	14
34	2d	$HCN \leftrightharpoons HNC$	$3.50e{+13}$	0.00	23800	
35	2d	$HCN \leftrightharpoons CN + H$	6.14e-06	-1.58	61500	Est
36	2d	$HCN \leftrightharpoons CN + H$	$2.55e{+}12$	0.00	0	
37	2d	$H + CO \leftrightharpoons CHO$	1.40e-34	0.00	100	15
38	2d	$H + CO \leftrightharpoons CHO$	1.96e-13	0.00	1370	
39	2d	$NCO \leftrightharpoons CO + N$	3.65e-10	0.00	27200	16
40	2d	$NCO \leftrightharpoons CO + N$	8.82e + 09	-1.00	27200	
41	2d	$CO_2 \leftrightharpoons CO + O$	1.81e-10	0.00	49000	17

Table 6—Continued

TABLE 0—Commuea								
#	Type	Reaction	α	β	γ	Ref		
42	2d	$CO_2 \leftrightharpoons CO + O$	8.99e + 12	0.00	65300			
43	2d	$H_2N \leftrightharpoons HN + H$	1.99e-09	0.00	38300	6		
44	2d	$H_2N \leftrightharpoons HN + H$	4.81e + 10	-1.00	38300			
45	2d	$HO + H \leftrightharpoons H_2O$	6.78e-31	-2.00	0	5		
46	2d	$HO + H \leftrightharpoons H_2O$	2.09e-10	0.00	0			
47	2d	HNO = NO + H	5.48e-07	-1.24	25300	18		
48	2d	$HNO \leftrightharpoons NO + H$	1.00e + 13	0.00	24200			
49	2d	$HO_2 \leftrightharpoons O_2 + H$	2.41e-08	-1.18	24400	7		
50	2d	$HO_2 \leftrightharpoons O_2 + H$	5.82e + 11	-2.18	24400			
51	2d	$N_2O \leftrightharpoons N_2 + O$	9.51e-10	0.00	29000	19		
52	2d	$N_2O \leftrightharpoons N_2 + O$	2.30e + 10	-1.00	29000			
53	2d	$NO + O \leftrightharpoons NO_2$	9.00e-32	-1.50	0	169		
54	2d	$NO + O \leftrightharpoons NO_2$	3.00e-11	0.00	0			
55	2d	$CH + H_2 \leftrightharpoons CH_3$	9.00e-31	0.00	550	21		
56	2d	$CH + H_2 \leftrightharpoons CH_3$	2.01e-10	0.15	0	20		
57	2d	$H + CH_2 \leftrightharpoons CH_3$	5.63e-31	0.00	0	21		
58	2d	$H + CH_2 \leftrightharpoons CH_3$	2.01e-11	0.15	0			
59	2d	$H_3N \leftrightharpoons H_2N + H$	2.96e-08	0.00	46300	22		
60	2d	$H_3N \leftrightharpoons H_2N + H$	6.60e + 17	0.00	49000			
61	2d	$H_3N \leftrightharpoons HN + H_2$	1.05e-09	0.00	47000	23		
62	2d	$H_3N \leftrightharpoons HN + H_2$	3.62e + 10	-1.00	47000			
63	2d	$NO_3 \leftrightharpoons NO + O_2$	2.51e-14	0.00	1230	24		
64	2d	$NO_3 \leftrightharpoons NO + O_2$	6.06e + 05	-1.00	1230			
65	2d	$H + CH_3 \leftrightharpoons CH_4$	8.90e-29	-1.80	318	31		
66	2d	$H + CH_3 \leftrightharpoons CH_4$	3.20e-10	0.13	25			
67	2d	$HN_2 \leftrightharpoons N_2 + H$	1.15e-10	-0.11	2510	25		
68	2d	$HN_2 \leftrightharpoons N_2 + H$	6.35e + 13	-0.53	3400			
69	2d	$C_2N \leftrightharpoons CNC$	5.00e-01	-5.16	57400	Est		
70	2d	$C_2N \leftrightharpoons CNC$	$1.21e{+18}$	-6.16	57400			
71	2d	CNO = CO + N	3.95 e-06	-1.90	30100	3		
72	2d	CNO = CO + N	$9.54e{+13}$	-2.90	30100			
73	2d	$H + C_2H \leftrightharpoons C_2H_2$	2.63e-26	-3.10	740	7		
74	2d	$H + C_2H \leftrightharpoons C_2H_2$	3.00e-10	0.00	0			
75	2d	$HCCN \leftrightharpoons CNC + H$	5.00e-01	-5.16	57400	Est		
76	2d	$HCCN \leftrightharpoons CNC + H$	$1.21e{+18}$	-6.16	57400			
77	2d	$NCCN \leftrightharpoons CN + CN$	2.97e-07	0.00	53600	26		
78	2d	$NCCN \leftrightharpoons CN + CN$	7.17e + 12	-1.00	53600			
79	2d	OCCN = CN + CO	2.97e-07	0.00	53600	Est		
80	2d	OCCN = CN + CO	7.17e + 12	-1.00	53600			
81	2d	$CH_2O \leftrightharpoons CHO + H$	6.20 e-09	0.00	36900	27		
82	2d	$CH_2O \leftrightharpoons CHO + H$	8.00e + 15	0.00	44100			

Table 6—Continued

		TABLE 0—C	отитиви			
#	Type	Reaction	α	β	γ	Ref
83	2d	$CH_2O \leftrightharpoons CO + H_2$	9.40e-09	0.00	33200	27
84	2d	$CH_2O \leftrightharpoons CO + H_2$	3.70e + 13	0.00	36200	
85	2d	$CHN_2 \leftrightharpoons CH + N_2$	2.97e-07	0.00	53600	Est
86	2d	$CHN_2 \leftrightharpoons CH + N_2$	7.17e + 12	-1.00	53600	
87	2d	HNCO = NCO + H	1.66e-07	0.00	56400	28
88	2d	HNCO = NCO + H	4.01e + 12	0.00	56400	
89	2d	HNCO = CO + HN	7.69e-04	-3.10	51400	3
90	2d	HNCO = CO + HN	6.00e + 13	0.00	50200	
91	2d	$HOCN \leftrightharpoons CN + HO$	1.66e-09	0.00	0	29
92	2d	$HOCN \leftrightharpoons CN + HO$	4.01e + 10	0.00	0	
93	2d	$HCNO \leftrightharpoons CNO + H$	1.66e-07	0.00	56400	28
94	2d	$HCNO \leftrightharpoons CNO + H$	4.01e + 12	0.00	56400	
95	2d	$HCNO \leftrightharpoons CN + HO$	1.66e-09	0.00	0	29
96	2d	$HCNO \leftrightharpoons CN + HO$	4.01e + 10	0.00	0	
97	2d	$HONC \leftrightharpoons CN + HO$	1.66e-09	0.00	0	29
98	2d	$HONC \leftrightharpoons CN + HO$	4.01e + 10	0.00	0	
99	2d	$H_2N_2 \leftrightharpoons H_2 + N_2$	1.00e-09	0.00	10000	Est
100	2d	$H_2N_2 \leftrightharpoons H_2 + N_2$	2.42e + 10	-1.00	10000	
101	2d	$H_2O_2 \leftrightharpoons HO + HO$	3.01e-08	0.00	21700	Est
102	2d	$H_2O_2 \leftrightharpoons HO + HO$	3.00e + 14	0.00	24400	
103	2d	$HNO_2 \leftrightharpoons HO + NO$	2.23e-03	-3.80	25200	18
104	2d	$HNO_2 \leftrightharpoons HO + NO$	1.09e + 16	-1.23	25000	
105	2d	$N_2O_2 \leftrightharpoons NO + NO$	1.00e-09	0.00	1500	Est
106	2d	$N_2O_2 \leftrightharpoons NO + NO$	2.42e + 10	-1.00	1500	
107	2d	$H + C_2H_2 \leftrightharpoons C_2H_3$	4.87e-30	-1.07	83	31
108	2d	$H + C_2H_2 \leftrightharpoons C_2H_3$	1.06e-11	1.64	1060	30
109	2d	$CH_3N \leftrightharpoons HCN + H_2$	5.00e-01	-5.16	57400	Est
110	2d	$CH_3N \leftrightharpoons HCN + H_2$	1.21e + 18	-6.16	57400	
111	2d	$CH_3O \leftrightharpoons CH_2O + H$	6.59 e-05	-2.70	15400	Est
112	2d	$CH_3O \leftrightharpoons CH_2O + H$	2.87e + 13	1.31	15800	
113	2d	$NO_2 + HO \leftrightharpoons HNO_3$	1.14e-06	0.00	23100	169
114	2d	$NO_2 + HO \leftrightharpoons HNO_3$	9.33e + 15	0.00	24700	
115	2d	$HO_2 + NO \leftrightharpoons HNO_3$	8.00e-02	-6.55	26100	169
116	2d	$HO_2 + NO \leftrightharpoons HNO_3$	5.56e + 17	-2.27	26300	
117	2d	$N_2O_3 \leftrightharpoons NO_2 + NO$	1.91e-07	-8.70	4880	32
118	2d	$N_2O_3 \leftrightharpoons NO_2 + NO$	4.70e + 15	0.40	4880	
119	2d	$H + C_2H_3 \leftrightharpoons C_2H_4$	1.49e-29	-1.00	0	21
120	2d	$H + C_2H_3 \leftrightharpoons C_2H_4$	2.30e-10	0.20	0	
121	2d	$C_2H_4 \leftrightharpoons C_2H_2 + H_2$	5.80 e-08	0.00	36000	33
122	2d	$C_2H_4 \leftrightharpoons C_2H_2 + H_2$	9.75e + 13	0.44	44700	
123	2d	$H + C_4H \leftrightharpoons C_4H_2$	2.64e-26	-3.10	72	21

Table 6—Continued

TABLE 0—Communeu									
#	Type	Reaction	α	β	γ	Ref			
124	2d	$H + C_4H \leftrightharpoons C_4H_2$	3.00e-10	0.00	0				
125	2d	$C_2H + C_2H \leftrightharpoons C_4H_2$	5.56e-28	-3.00	300	31			
126	2d	$C_2H + C_2H \leftrightharpoons C_4H_2$	2.60e-10	0.00	0				
127	2d	$H + C_4H_2 \leftrightharpoons C_4H_3$	5.53e-25	-2.93	176	31			
128	2d	$H + C_4H_2 \leftrightharpoons C_4H_3$	2.66e-12	5.55	0				
129	2d	$H + C_4H_3 \leftrightharpoons C_4H_4$	5.41e-23	-3.97	177	31			
130	2d	$H + C_4H_3 \leftrightharpoons C_4H_4$	1.39e-10	0.00	0				
131	2d	$H_4N_2 \leftrightharpoons H_2N + H_2N$	6.61e-09	0.00	20600	34			
132	2d	$H_4N_2 \leftrightharpoons H_2N + H_2N$	7.94e + 13	0.00	27700				
133	2d	$H_4O_2 \leftrightharpoons H_2O + H_2O$	1.00e-09	0.00	1500	Est			
134	2d	$H_4O_2 \leftrightharpoons H_2O + H_2O$	$2.42e{+10}$	-1.00	1500				
135	2d	$H + C_2H_4 \leftrightharpoons C_2H_5$	9.23e-29	-1.51	73	31			
136	2d	$H + C_2H_4 \leftrightharpoons C_2H_5$	1.08e-12	5.31	0				
137	2d	$CH_5N \leftrightharpoons CH_3 + H_2N$	5.25e-11	0.00	17700	35			
138	2d	$CH_5N \leftrightharpoons CH_3 + H_2N$	6.92e + 10	0.00	24200				
139	2d	$CH_5N \leftrightharpoons CH_4 + HN$	2.66e-11	0.00	24300	36			
140	2d	$CH_5N \leftrightharpoons CH_4 + HN$	6.43e + 08	-1.00	24300				
141	2d	$CH_3 + CH_3 \leftrightharpoons C_2H_6$	3.05e-26	-3.77	62	31			
142	2d	$CH_3 + CH_3 \leftrightharpoons C_2H_6$	6.78e-11	-0.36	30				
143	2d	$H + C_2H_5 \leftrightharpoons C_2H_6$	2.00e-28	-1.50	0	31			
144	2d	$H + C_2H_5 \leftrightharpoons C_2H_6$	1.70e-10	0.00	0				
145	2d	$C_2H_6 \leftrightharpoons C_2H_4 + H_2$	3.80e-07	0.00	34000	37			
146	2d	$C_2H_6 \leftrightharpoons C_2H_4 + H_2$	9.18e + 12	-1.00	34000				
147	2d	$C_3H_4 \leftrightharpoons C_2H_2 + CH_2$	2.19e-10	1.00	27900	Est			
148	2d	$C_3H_4 \leftrightharpoons C_2H_2 + CH_2$	5.30e + 09	0.00	27900				
149	2d	$C_3H_4 \leftrightharpoons C_2H_4 + C$	2.40e-13	1.00	20100	Est			
150	2d	$C_3H_4 \leftrightharpoons C_2H_4 + C$	5.79e + 06	0.00	20100				
151	2d	$C_3H_4 \leftrightharpoons CH_4 + C + C$	2.82e-11	1.00	23500	Est			
152	2d	$C_3H_4 \leftrightharpoons CH_4 + C + C$	6.81e-08	0.00	23500				
153	2d	$C_3H_4 \leftrightharpoons C_3H_3 + H$	7.80e-06	0.00	40300	Est			
154	2d	$C_3H_4 \leftrightharpoons C_3H_3 + H$	1.88e + 14	-1.00	40300				
155	2d	$C_3H_3 \leftrightharpoons C_2H_2 + CH$	1.00e-14	0.00	0	Est			
156	2d	$C_3H_3 \leftrightharpoons C_2H_2 + CH$	2.00e + 05	0.00	0				
157	2d	$C_3H_5 \leftrightharpoons C_3H_4 + H$	4.14e-05	1.00	32000	38			
158	2d	$C_3H_5 \leftrightharpoons C_3H_4 + H$	1.00e + 15	0.00	32000				
159	2d	$C_3H_5 \leftrightharpoons C_2H_2 + CH_3$	5.22 e-07	1.00	16800	39			
160	2d	$C_3H_5 \leftrightharpoons C_2H_2 + CH_3$	1.26e + 13	0.00	16800				
161	2d	$HOCH = CO + H_2$	9.40e-09	0.00	33200	27			
162	2d	$HOCH = CO + H_2$	3.70e + 13	0.00	36200				
163	2d	$HOCH \leftrightharpoons CHO + H$	6.20e-09	0.00	36900	27			
100	2u	$110011 \rightarrow 0110 + 11$	0.200 05	0.00	00000	41			

Table 6—Continued

TABLE 0—Continued						
#	Type	Reaction	α	β	γ	Ref
165	2d	$HC_3N \leftrightharpoons HCN + C_2$	1.00e-08	0.00	81900	Est
166	2d	$HC_3N \leftrightharpoons HCN + C_2$	2.42e + 11	-1.00	81900	
167	2d	$NH_2O \leftrightharpoons H_2 + NO$	4.14e-07	1.00	6830	40
168	2d	$NH_2O \leftrightharpoons H_2 + NO$	1.00e + 13	0.00	6830	
169	2d	$HCCO \leftrightharpoons CO + CH$	1.08e-08	0.00	29600	41
170	2d	$HCCO \leftrightharpoons CO + CH$	$2.61e{+11}$	-1.00	29600	
171	2d	$C_4H_3 \leftrightharpoons C_2H_2 + C_2H$	5.34e-05	1.00	41500	Est
172	2d	$C_4H_3 \leftrightharpoons C_2H_2 + C_2H$	1.29e + 15	0.00	41500	
173	2d	$C_4H_4 \leftrightharpoons C_2H_2 + C_2H_2$	5.34 e-05	1.00	41500	42
174	2d	$C_4H_4 \leftrightharpoons C_2H_2 + C_2H_2$	1.29e + 15	0.00	41500	
175	2d	$C_4H_6 \leftrightharpoons C_4H_4 + H_2$	2.90e-05	1.00	47800	Est
176	2d	$C_4H_6 \leftrightharpoons C_4H_4 + H_2$	7.00e + 14	0.00	47800	
177	2d	$C_4H_6 \leftrightharpoons C_3H_3 + CH_3$	4.14e-08	1.00	30000	43
178	2d	$C_4H_6 \leftrightharpoons C_3H_3 + CH_3$	1.00e + 12	0.00	30000	
179	2d	$C_4H_6 \leftrightharpoons C_2H_3 + C_2H_3$	1.27e-07	1.00	33600	43
180	2d	$C_4H_6 \leftrightharpoons C_2H_3 + C_2H_3$	3.07e + 12	0.00	33600	
181	2d	$C_4H_6 \leftrightharpoons C_2H_4 + C_2H_2$	2.90e-07	1.00	33800	43
182	2d	$C_4H_6 \leftrightharpoons C_2H_4 + C_2H_2$	7.00e + 12	0.00	33800	
183	2d	$HNNH \leftrightharpoons N_2 + H_2$	1.00e-08	0.00	10000	Est
184	2d	$HNNH \leftrightharpoons N_2 + H_2$	2.42e + 11	-1.00	10000	
185	2d	$HNNH \leftrightharpoons HN + HN$	1.00e-08	0.00	70000	Est
186	2d	$HNNH \leftrightharpoons HN + HN$	2.42e + 11	-1.00	70000	
187	2d	$H_2CN \leftrightharpoons HCN + H$	1.00e-08	0.00	27000	44
188	2d	$H_2CN \leftrightharpoons HCN + H$	2.42e + 11	-1.00	27000	
189	2d	$CH_2CN \leftrightharpoons CH_2 + CN$	5.00e-01	-5.16	57400	Est
190	2d	$CH_2CN \leftrightharpoons CH_2 + CN$	$1.21e{+18}$	-6.16	57400	
191	2d	$C_2H_2O \leftrightharpoons CH_2 + CO$	5.98e-09	0.00	29000	45
192	2d	$C_2H_2O \leftrightharpoons CH_2 + CO$	3.00e + 14	0.00	35700	
193	2d	$HCOCN \leftrightharpoons HNC + CO$	9.23e-06	1.00	32100	46
194	2d	$HCOCN \leftrightharpoons HNC + CO$	2.23e + 14	0.00	32100	
195	2d	$HCOCN \leftrightharpoons HCN + CO$	1.00e-05	1.00	33100	46
196	2d	$HCOCN \leftrightharpoons HCN + CO$	2.42e + 14	0.00	33100	
197	2d	$CH_2OH \leftrightharpoons CH_2O + H$	1.66e-10	0.00	12600	47
198	2d	$CH_2OH \leftrightharpoons CH_2O + H$	5.60e + 10	0.00	14600	
199	2d	$CH_2N_2 \leftrightharpoons CH_2 + N_2$	4.97e-08	1.00	17100	48
200	2d	$CH_2N_2 \leftrightharpoons CH_2 + N_2$	1.20e + 12	0.00	17100	
201	2d	$CH_2O_2 \leftrightharpoons CO_2 + H_2$	2.81e-09	0.00	25700	Est
202	2d	$CH_2O_2 \leftrightharpoons CO_2 + H_2$	4.46e + 13	0.00	34400	
203	2d	$HCOOH = CO_2 + H_2$	2.81e-09	0.00	25700	49
204	2d	$HCOOH = CO_2 + H_2$	4.46e + 13	0.00	34400	
205	2d	$HCOOH = H_2O + CO$	6.73e-09	0.00	26700	49

Table 6—Continued

		TABLE 0—Co	пиниеи			
#	Type	Reaction	α	β	γ	Ref
206	2d	$HCOOH = H_2O + CO$	7.49e + 14	0.00	34500	
207	2d	$HCOOH = CH_2O_2$	1.20e-12	0.00	0	49
208	2d	$HCOOH = CH_2O_2$	2.90e + 07	-1.00	0	
209	2d	$CH_3CN \leftrightharpoons C_2H_3N$	4.17e-11	0.00	19100	50
210	2d	$CH_3CN \leftrightharpoons C_2H_3N$	1.01e + 09	-1.00	19100	
211	2d	$CH_3CN \leftrightharpoons CH_2CN + H$	4.00e-04	1.00	48400	51
212	2d	$CH_3CN \leftrightharpoons CH_2CN + H$	1.00e + 16	0.00	48400	
213	2d	$C_2H_3N \leftrightharpoons CH_2CN + H$	4.00e-04	1.00	48400	Est
214	2d	$C_2H_3N \leftrightharpoons CH_2CN + H$	1.00e + 16	0.00	48400	
215	2d	$C_2H_3O \leftrightharpoons CH_2CHO$	1.24e-04	1.00	14200	52
216	2d	$C_2H_3O \leftrightharpoons CH_2CHO$	3.00e + 15	0.00	14200	
217	2d	$C_2H_3O \leftrightharpoons CH_3 + CO$	5.25e-10	0.00	6040	53
218	2d	$C_2H_3O \leftrightharpoons CH_3 + CO$	2.00e + 10	0.00	7550	
219	2d	$C_2H_2 + HO \leftrightharpoons C_2H_3O$	5.00e-30	-1.50	0	54
220	2d	$C_2H_2 + HO \leftrightharpoons C_2H_3O$	9.00e-13	2.00	0	
221	2d	$C_2H_3O \leftrightharpoons C_2H_2O + H$	3.61e-07	2.94	23100	55
222	2d	$C_2H_3O \leftrightharpoons C_2H_2O + H$	8.74e + 12	1.94	23100	
223	2d	$CH_3OH \leftrightharpoons H_2O + CH_2$	1.16e-08	0.00	33400	56
224	2d	$CH_3OH \leftrightharpoons H_2O + CH_2$	2.80e + 11	-1.00	33400	
225	2d	$CH_3OH \leftrightharpoons CH_2OH + H$	2.16e-08	0.00	33600	57
226	2d	$CH_3OH \leftrightharpoons CH_2OH + H$	2.30e + 10	5.04	42500	
227	2d	$HO + CH_3 \leftrightharpoons CH_3OH$	6.40e-29	0.00	1030	21
228	2d	$HO + CH_3 \leftrightharpoons CH_3OH$	6.33e-11	0.10	0	
229	2d	$CH_3OH \leftrightharpoons CH_3O + H$	4.04e-07	3.39	50200	58
230	2d	$CH_3OH \leftrightharpoons CH_3O + H$	9.75e + 12	2.39	50200	
231	2d	$CH_3OH \leftrightharpoons HOCH + H_2$	8.78e-07	2.22	43500	58
232	2d	$CH_3OH \leftrightharpoons HOCH + H_2$	2.12e + 13	1.22	43500	
233	2d	$C_2H_4O \leftrightharpoons CH_3 + CHO$	2.48e-05	1.00	39800	59
234	2d	$C_2H_4O \leftrightharpoons CH_3 + CHO$	6.00e + 14	0.00	39800	
235	2d	$C_2H_4O \leftrightharpoons C_2H_2O + H_2$	1.24 e-05	1.00	42200	59
236	2d	$C_2H_4O \leftrightharpoons C_2H_2O + H_2$	3.00e + 14	0.00	42200	
237	2d	$C_2H_4O \leftrightharpoons CH_4 + CO$	4.14e-05	1.00	42800	59
238	2d	$C_2H_4O \leftrightharpoons CH_4 + CO$	1.00e + 15	0.00	42800	
239	2d	$CH_4O_2 \leftrightharpoons CH_3O + HO$	2.48e-05	1.00	21300	33
240	2d	$CH_4O_2 \leftrightharpoons CH_3O + HO$	6.00e + 14	0.00	21300	
241	2d	$C_2H_6N \leftrightharpoons CH_3N + CH_3$	5.25 e-11	0.00	17700	Est
242	2d	$C_2H_6N \leftrightharpoons CH_3N + CH_3$	6.92e + 10	0.00	24200	
243	2d	$NH_2OH \leftrightharpoons H_2N + HO$	9.30e-11	0.20	45800	60
244	2d	$NH_2OH \leftrightharpoons H_2N + HO$	2.25e + 09	-0.80	45800	
245	2d	$C_3H_3N \leftrightharpoons HC_3N + H_2$	8.28 e-07	1.00	38700	61
246	2d	$C_3H_3N \leftrightharpoons HC_3N + H_2$	2.00e + 13	0.00	38700	

Table 6—Continued

		TABLE 0—Con				
#	Type	Reaction	α	β	γ	Ref
247	2d	$C_3H_3N \leftrightharpoons C_2H_2 + HCN$	7.37e-08	1.00	34200	61
248	2d	$C_3H_3N \leftrightharpoons C_2H_2 + HCN$	1.78e + 12	0.00	34200	
249	2d	$C_3H_3O \leftrightharpoons C_2H_3 + CO$	5.22e-06	1.63	13700	55
250	2d	$C_3H_3O \leftrightharpoons C_2H_3 + CO$	1.26e + 14	0.63	13700	
251	2d	$CH_3NO \leftrightharpoons HCN + H_2O$	5.25 e-11	0.00	25300	62
252	2d	$CH_3NO \leftrightharpoons HCN + H_2O$	1.27e + 09	-1.00	25300	
253	2d	$C_4H_{10} \leftrightharpoons C_2H_5 + C_2H_5$	7.84e-06	0.00	24900	63
254	2d	$C_4H_{10} \leftrightharpoons C_2H_5 + C_2H_5$	2.72e + 15	0.00	38000	
255	2d	$C_3H_2O \leftrightharpoons C_2H_2 + CO$	3.52e-05	1.00	35700	64
256	2d	$C_3H_2O \leftrightharpoons C_2H_2 + CO$	$8.51e{+14}$	0.00	35700	
257	2d	$CH_3O_2 \leftrightharpoons CH_3 + O_2$	2.03e+00	-10.00	16700	7
258	2d	$CH_3O_2 \leftrightharpoons CH_3 + O_2$	4.90e + 19	-11.00	16700	
259	2d	$CH_2CHO \leftrightharpoons C_2H_2O + H$	1.00e-12	0.00	20700	65
260	2d	$CH_2CHO \leftrightharpoons C_2H_2O + H$	2.42e + 07	-1.00	20700	
261	2d	$CH_2CHO \leftrightharpoons CH_3 + CO$	1.00e-09	0.00	20700	66
262	2d	$CH_2CHO \leftrightharpoons CH_3 + CO$	2.42e + 10	-1.00	20700	
263	2d	$C_2H_2O_2 \leftrightharpoons CHO + CHO$	1.06e + 04	-9.90	41300	67
264	2d	$C_2H_2O_2 \leftrightharpoons CHO + CHO$	2.57e + 23	-10.90	41300	
265	2d	$H_2NNO_2 \leftrightharpoons H_2N + NO_2$	1.00e-09	0.00	5000	Est
266	2d	$H_2NNO_2 \leftrightharpoons H_2N + NO_2$	2.42e + 10	-1.00	5000	
267	2d	$Oxyrane = CH_2CHO + H$	2.38e-06	1.20	36100	68
268	2d	Oxyrane \rightleftharpoons CH ₂ CHO + H	5.75e + 13	0.20	36100	
269	2d	Oxyrane \rightleftharpoons C ₂ H ₃ O + H	4.18e-06	1.25	32800	68
270	2d	Oxyrane \rightleftharpoons C ₂ H ₃ O + H	1.01e + 14	0.25	32800	
271	2d	Oxyrane \rightleftharpoons CH ₃ + CHO	2.25 e-05	1.40	31200	68
272	2d	Oxyrane \rightleftharpoons CH ₃ + CHO	$5.44e{+}14$	0.40	31200	
273	2d	$Oxyrane = C_2H_2O + H_2$	4.72e-08	0.80	31800	68
274	2d	$Oxyrane \leftrightharpoons C_2H_2O + H_2$	1.14e + 12	-0.20	31800	
275	2d	Oxyrane \rightleftharpoons C ₂ H ₄ O	1.83e-09	0.25	23300	68
276	2d	Oxyrane \rightleftharpoons C ₂ H ₄ O	4.43e + 10	-0.75	23300	
277	2d	Oxyrane \rightleftharpoons C ₂ H ₂ + H ₂ O	4.43e-07	1.06	35000	68
278	2d	Oxyrane \rightleftharpoons C ₂ H ₂ + H ₂ O	1.07e + 13	0.06	35000	
279	2d	$Oxyrane = CH_4 + CO$	8.28e-07	1.11	32100	68
280	2d	$Oxyrane = CH_4 + CO$	2.00e + 13	0.11	32100	
281	2d	$CH_3N_2H \leftrightharpoons HCN + H_3N$	2.66e-11	0.00	24300	69
282	2d	$CH_3N_2H \leftrightharpoons HCN + H_3N$	2.66e-11	-1.00	24300	
283	2d	$CH_3NO_2 \leftrightharpoons CH_3 + NO_2$	3.32e-07	0.00	21100	70
284	2d	$CH_3NO_2 \leftrightharpoons CH_3 + NO_2$	$1.58e{+}16$	0.00	30000	
285	2d	$CH_3ONO \leftrightharpoons CH_2O + HNO$	1.15e-06	1.00	19500	71
286	2d	$CH_3ONO \leftrightharpoons CH_2O + HNO$	2.77e + 13	0.00	19500	
287	2d	$CH_3ONO \leftrightharpoons CH_3O + NO$	1.32e-06	0.00	17200	71

Table 6—Continued

TABLE 0—Continued							
#	Type	Reaction	α	β	γ	Ref	
288	2d	$CH_3ONO \leftrightharpoons CH_3O + NO$	1.06e + 15	0.00	18000		
289	2d	$CH_3NO_3 \leftrightharpoons CH_3O + NO_2$	4.14e-07	1.00	16800	72	
290	2d	$CH_3NO_3 \leftrightharpoons CH_3O + NO_2$	1.00e + 13	0.00	16800		
291	2d	$C_2H_5OH = CH_2OH + CH_3$	5.42e + 14	-18.90	57700	73	
292	2d	$C_2H_5OH = CH_2OH + CH_3$	2.99e + 18	-2.16	44300		
293	2d	$C_2H_5OH = C_2H_5 + HO$	1.14e + 16	-19.70	57600	73	
294	2d	$C_2H_5OH \leftrightharpoons C_2H_5 + HO$	1.37e + 17	-2.16	48600		
295	2d	$C_2H_5OH \leftrightharpoons C_2H_4 + H_2O$	2.05e + 12	-17.90	42700	73	
296	2d	$C_2H_5OH = C_2H_4 + H_2O$	1.41e + 13	1.36	33100		
297	2d	$(CH_3)_2O = CH_3O + CH_3$	1.25 e-08	0.00	21500	74	
298	2d	$(CH_3)_2O \leftrightharpoons CH_3O + CH_3$	5.71e + 17	-1.57	42200		
299	2d	$(CH_3)_2O = CH_2O + CH_4$	4.17e-11	0.00	20500	75	
300	2d	$(CH_3)_2O = CH_2O + CH_4$	1.53e + 13	0.00	29400	76	
301	2d	$C_2H_5NO = C_2H_2O + H_3N$	2.07e-05	1.00	36900	77	
302	2d	$C_2H_5NO = C_2H_2O + H_3N$	5.01e + 14	0.00	36900		
303	2d	$C_2H_5OO = CH_3CH_2O + O$	7.37e-05	0.91	31000	78	
304	2d	$C_2H_5OO = CH_3CH_2O + O$	1.78e + 15	-0.09	31000		
305	2d	$C_2H_5OO \leftrightharpoons C_2H_5 + O_2$	1.40e + 02	-9.85	19600	78	
306	2d	$C_2H_5OO \leftrightharpoons C_2H_5 + O_2$	5.30e + 15	-0.83	17200		
307	2d	$C_2H_5OO = C_2H_4O + HO$	1.34e-07	2.37	20900	78	
308	2d	$C_2H_5OO \leftrightharpoons C_2H_4O + HO$	3.24e + 12	1.37	20900		
309	2d	$C_2H_5OO \leftrightharpoons C_2H_4 + HO_2$	3.59e-05	-5.88	17100	79	
310	2d	$C_2H_5OO \leftrightharpoons C_2H_4 + HO_2$	8.66e + 14	-6.88	17100		
311	2d	$C_2H_4O_3 \leftrightharpoons CH_2O + H_2O + CO$	4.43e-06	1.00	25300	80	
312	2d	$C_2H_4O_3 \leftrightharpoons CH_2O + H_2O + CO$	1.07e + 14	0.00	25300		
313	2d	$(CH_3N)_2 \leftrightharpoons CH_3 + CH_3 + N_2$	8.28e-09	1.00	16800	81	
314	2d	$(CH_3N)_2 \leftrightharpoons CH_3 + CH_3 + N_2$	2.00e + 11	0.00	16800		
315	2d	$(CH_3O)_2 \leftrightharpoons CH_3O + CH_3O$	1.04e-03	1.00	19400	82	
316	2d	$(CH_3O)_2 \leftrightharpoons CH_3O + CH_3O$	2.51e + 16	0.00	19400		
317	2d	$\text{cyc-C}_2\text{H}_3\text{O} \leftrightharpoons \text{CH}_2\text{CHO}$	3.06e-05	-5.90	7540	68	
318	2d	$\text{cyc-C}_2\text{H}_3\text{O} \leftrightharpoons \text{CH}_2\text{CHO}$	7.40e + 14	-6.90	7540		
319	2d	$\text{cyc-C}_2\text{H}_3\text{O} \leftrightharpoons \text{CH}_3 + \text{CO}$	3.03e-07	1.00	7190	Est	
320	2d	$\text{cyc-C}_2\text{H}_3\text{O} \leftrightharpoons \text{CH}_3 + \text{CO}$	7.31e + 12	0.00	7190		
321	2d	$\text{cyc-C}_2\text{H}_3\text{O} \leftrightharpoons \text{C}_2\text{H}_2\text{O} + \text{H}$	2.05e-06	1.00	7480	68	
322	2d	$\operatorname{cyc-C_2H_3O} \leftrightharpoons \operatorname{C_2H_2O} + \operatorname{H}$	4.96e + 13	0.00	7480		
323	2d	$CH_3OCO = CH_3O + CO$	1.35e-06	1.65	10600	55	
324	2d	$CH_3OCO = CH_3O + CO$	3.27e + 13	0.65	10600		
325	2d	$CH_3OCO = CH_3 + CO_2$	1.14e-06	2.11	7990	55	
326	2d	$CH_3OCO = CH_3 + CO_2$	2.76e + 13	1.11	7990		
327	2d	$C_2H_6O_2 \leftrightharpoons CH_3CH_2O + HO$	1.66e-04	1.00	21700	33	
328	2d	$C_2H_6O_2 \leftrightharpoons CH_3CH_2O + HO$	4.00e + 15	0.00	21700		
-		_ 0 _ 0 - 2 - 1 0					

Table 6—Continued

TABLE 0—Continued							
#	Type	Reaction	α	β	γ	Ref	
329	2d	$H_2C_2HOH \leftrightharpoons CH_3 + CHO$	2.48e-05	1.00	39800	Est	
330	2d	$H_2C_2HOH \leftrightharpoons CH_3 + CHO$	6.00e + 14	0.00	39800		
331	2d	$CH_3COOH \leftrightharpoons C_2H_2O + H_2O$	5.50e-12	0.00	19700	83	
332	2d	$CH_3COOH = C_2H_2O + H_2O$	2.82e + 12	0.00	32700		
333	2d	$CH_3COOH \leftrightharpoons CH_4 + CO_2$	2.93e-06	1.00	37500	84	
334	2d	$CH_3COOH \leftrightharpoons CH_4 + CO_2$	7.08e + 13	0.00	37500		
335	2d	$C_2H_3NO_2 \leftrightharpoons CH_2CHO + NO$	1.32e-06	0.00	17200	Est	
336	2d	$C_2H_3NO_2 \leftrightharpoons CH_2CHO + NO$	1.60e + 15	0.00	18000		
337	2d	$(CH_2OH)_2 \leftrightharpoons CH_3CH_2O + HO$	1.66e-04	1.00	21700	33	
338	2d	$(CH_2OH)_2 \leftrightharpoons CH_3CH_2O + HO$	$4.00e{+15}$	0.00	21700		
339	2d	$C_2H_5NO_2 \leftrightharpoons C_2H_4 + HNO_2$	2.32e-08	1.00	21600	85	
340	2d	$C_2H_5NO_2 \leftrightharpoons C_2H_4 + HNO_2$	$5.60e{+11}$	0.00	21600		
341	2d	$C_2H_5NO_2 \leftrightharpoons C_2H_5 + NO_2$	1.66e-06	0.00	18000	86	
342	2d	$C_2H_5NO_2 \leftrightharpoons C_2H_5 + NO_2$	7.94e + 15	0.00	28800		
343	2d	$C_2H_5NO_2 \leftrightharpoons CH_3NO + CH_2O$	2.42e-11	0.50	2340	Est	
344	2d	$C_2H_5NO_2 \leftrightharpoons CH_3NO + CH_2O$	5.85e + 08	-0.50	2340		
345	2d	$aCO2H5N \leftrightharpoons C_2H_4 + HNO_2$	2.32e-08	1.00	21600	85	
346	2d	$aCO2H5N \leftrightharpoons C_2H_4 + HNO_2$	$5.60e{+11}$	0.00	21600		
347	2d	$aCO2H5N \leftrightharpoons C_2H_5 + NO_2$	1.66e-06	0.00	18000	86	
348	2d	$aCO2H5N \leftrightharpoons C_2H_5 + NO_2$	7.94e + 15	0.00	28800		
349	2d	$bCO2H5N \leftrightharpoons CH_3CH_2O + NO$	2.53e-06	1.00	18900	87	
350	2d	$bCO2H5N \leftrightharpoons CH_3CH_2O + NO$	6.10e + 13	0.00	18900		
351	2d	$bCO2H5N \leftrightharpoons C_2H_4O + HNO$	2.61e-06	1.00	18900	88	
352	2d	$bCO2H5N \leftrightharpoons C_2H_4O + HNO$	6.31e + 13	0.00	18900		
353	2d	$CH_3OCH_2 \leftrightharpoons CH_2O + CH_3$	2.09e-10	0.00	9560	89	
354	2d	$CH_3OCH_2 \leftrightharpoons CH_2O + CH_3$	1.27e + 14	-0.22	13700		
355	2d	$CH_3CHOH \leftrightharpoons C_2H_4O + H$	8.30e-11	0.00	11000	90	
356	2d	$CH_3CHOH \leftrightharpoons C_2H_4O + H$	2.00e+09	-1.00	11000		
357	2d	$CH_2NCH_3 \leftrightharpoons CH_3CN + H_2$	1.00e-08	1.00	7950	91	
358	2d	$CH_2NCH_3 \leftrightharpoons CH_3CN + H_2$	2.10e + 17	0.00	7950		
359	2d	$(CH_3)_2CO \leftrightharpoons CH_2O + C_2H_4$	1.09e-04	1.00	31200	92	
360	2d	$(CH_3)_2CO \leftrightharpoons CH_2O + C_2H_4$	2.63e + 15	0.00	31200		
361	2d	$(CH_3)_2CO = cyc-C_2H_3O + CH_3$	1.33e-08	0.00	46300	93	
362	2d	$(CH_3)_2CO = cyc-C_2H_3O + CH_3$	$3.21e{+11}$	-1.00	46300		
363	2d	$(CH_3)_2CO \leftrightharpoons C_2H_5 + CHO$	1.01 e-06	1.00	29400	93	
364	2d	$(CH_3)_2CO \leftrightharpoons C_2H_5 + CHO$	2.45e + 13	0.00	29400		
365	2d	$(CH_3)_2CO \leftrightharpoons C_2H_3O + CH_3$	5.80e-06	1.00	35700	94	
366	2d	$(CH_3)_2CO \leftrightharpoons C_2H_3O + CH_3$	1.40e + 14	0.00	35700		
367	2d	$CH_3CH_2O \leftrightharpoons CH_3CHOH$	3.29e-07	1.00	14800	95	
368	2d	$CH_3CH_2O \leftrightharpoons CH_3CHOH$	1.87e + 00	12.40	2130	96	
369	2d	$CH_3CH_2O \leftrightharpoons C_2H_4O + H$	1.76e-07	2.42	10300	97	

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
370	2d	$CH_3CH_2O \leftrightharpoons C_2H_4O + H$	4.24e + 12	1.42	10300	
371	2d	$CH_3CH_2O \leftrightharpoons CH_2O + CH_3$	5.51e-05	-1.02	10400	98
372	2d	$CH_3CH_2O \leftrightharpoons CH_2O + CH_3$	$1.33e{+}15$	-2.02	10400	
373	2d	$Na + HO \leftrightharpoons NaOH$	1.90e-25	-2.21	41	99
374	2d	$Na + HO \leftrightharpoons NaOH$	1.00e-11	0.00	0	100
375	2d	$Na + H \leftrightharpoons NaH$	1.90e-25	-2.21	41	100
376	2d	$Na + H \leftrightharpoons NaH$	1.00e-11	0.00	41	
377	2d	$K + HO \leftrightharpoons KOH$	1.90e-25	-2.21	41	99
378	2d	$K + HO \leftrightharpoons KOH$	1.00e-11	0.00	41	100
379	2d	$K + H \leftrightharpoons KH$	1.90e-25	-2.21	41	100
380	2d	$K + H \leftrightharpoons KH$	1.00e-11	0.00	41	• • •
381	2d	$HCl \leftrightharpoons Cl + H$	7.31e-11	0.00	41000	101
382	2d	$HCl \leftrightharpoons Cl + H$	1.81e + 09	-1.00	41000	• • •
383	2d	$O(^{1}D) + N_{2} \leftrightharpoons N_{2}O$	2.80e-36	-0.90	0	21
384	2d	$O(^{1}D) + N_{2} \leftrightharpoons N_{2}O$	6.76e-17	-1.90	0	
385	2d	$CH_3OH \leftrightharpoons CH_2^* + H_2O$	3.94e-04	-0.02	46200	21
386	2d	$CH_3OH \leftrightharpoons CH_2^* + H_2O$	9.51e + 15	-1.02	46200	
387	2d	$HN^* \leftrightharpoons HN$	1.35e-10	0.00	0	102
388	2d	$HN^* \leftrightharpoons HN$	3.29e+09	-1.00	0	• • •
389	3i	$Ar^+ + Ar \leftrightharpoons Ar_2^+$	1.46e-31	0.00	0	103
390	3i	$Ar^+ + Ar \leftrightharpoons Ar_2^+$	3.53e-12	-1.00	0	• • •
391	3i	$C^+ + H_2 \leftrightharpoons CH_2^+$	2.10e-29	0.00	0	104
392	3i	$C^+ + H_2 \leftrightharpoons CH_2^+$	5.07e-10	-1.00	0	• • •
393	3i	$CH_3^+ + H_2 \leftrightharpoons CH_5^+$	1.10e-28	0.00	0	105
394	3i	$CH_3^+ + H_2 \leftrightharpoons CH_5^+$	2.66e-09	-1.00	0	• • •
395	3i	$C_2H_2^+ + C_2H_2 \leftrightharpoons C_4H_4^+$	1.60e-26	0.00	0	106
396	3i	$C_2H_2^+ + C_2H_2 \leftrightharpoons C_4H_4^+$	3.86e-07	-1.00	0	
397	3i	$C_2H_2^+ + H_2 \leftrightharpoons C_2H_4^+$	1.20e-27	0.00	0	107
398	3i	$C_2H_2^+ + H_2 \leftrightharpoons C_2H_4^+$	2.90e-08	-1.00	0	• • •
399	3i	$C_2H_3^+ + H_2 \leftrightharpoons C_2H_5^+$	1.49e-29	0.00	0	107
400	3i	$C_2H_3^+ + H_2 \leftrightharpoons C_2H_5^+$	3.60e-10	-1.00	0	• • •
401	3i	$C_2H_4^+ + C_2H_4 \leftrightharpoons C_4H_8^+$	6.30e-26	0.00	0	107
402	3i	$C_2H_4^+ + C_2H_4 \leftrightharpoons C_4H_8^+$	1.52e-06	-1.00	0	• • •
403	3i	$Fe^+ + O_2 \leftrightharpoons FeO_2^+$	1.00e-30	0.00	0	108
404	3i	$Fe^+ + O_2 = FeO_2^+$	2.42e-11		0	• • •
405	3i	$H^+ + H_2 \leftrightharpoons H_3^+$	3.05e-29	0.00	0	109
406	3i	$H^+ + H_2 \leftrightharpoons H_3^+$	7.37e-10	-1.00	0	
407	3i	$H_3^+ + Ar \leftrightharpoons Ar H_3^+$	1.00e-31	0.00	0	110
408	3i	$H_3^+ + Ar \leftrightharpoons ArH_3^+$	2.42e-12	-1.00	0	
409	3i	$H_3^+ + O_2 \leftrightharpoons H_3O_2^+$	3.00e-29	0.00	0	111
410	3i	$H_3^+ + O_2 \leftrightharpoons H_3O_2^+$	7.25e-10	-1.00	0	• • •

Table 6—Continued

$\begin{array}{cccccccccccccccccccccccccccccccccccc$	#	Туре	Reaction	α	β	γ	Ref
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	411	3i	$\mathrm{He^+} + \mathrm{He} \leftrightharpoons \mathrm{He}_2^+$	1.06e-31	-1.00	0	112
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	412	3i	$\mathrm{He^+} + \mathrm{He} \leftrightharpoons \mathrm{He}_2^+$	2.56e-12	-2.00	0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	413	3i	$Mg^+ + O_2 \leftrightharpoons MgO_2^+$	2.50e-30	0.00	0	108
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	414	3i	$Mg^+ + O_2 \leftrightharpoons MgO_2^+$	6.04e-11	-1.00	0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	415	3i	$N^+ + N_2 \leftrightharpoons N_3^+$	2.00e-28	0.00	0	113
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	416	3i	$N^+ + N_2 \leftrightharpoons N_3^+$	4.83e-09	-1.00	0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	417	3i	$NO_2^+ + H_2O \rightleftharpoons H_2NO_3^+$	5.00e-28	0.00	0	114
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	418	3i	$NO_2^+ + H_2O \leftrightharpoons H_2NO_3^+$	1.21e-08	-1.00	0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	419	3i		4.60e-30	0.00	0	115
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	420	3i	$O_2^{\frac{1}{7}} + CO_2 \leftrightharpoons CO_4^{\frac{1}{7}}$	1.11e-10	-1.00	0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	421	ti	$C = C^+ + e^-$		0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	422	ti	$C \leftrightharpoons C^+ + e^-$	2.77e + 10	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	423	ti	$H \leftrightharpoons H^+ + e^-$	5.31e-12	0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	424	$_{ m ti}$	$H \leftrightharpoons H^+ + e^-$	1.28e + 08	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	425	$_{ m ti}$	$N \leftrightharpoons N^+ + e^-$	1.83e-09	0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	426	$_{ m ti}$	$N \leftrightharpoons N^+ + e^-$	$4.41e{+10}$	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	427	$_{ m ti}$	$O \leftrightharpoons O^+ + e^-$	2.72e-09	0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	428	$_{ m ti}$		6.57e + 10	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	429	$_{ m ti}$		3.10e-08	0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	430	$_{ m ti}$	$Ar \leftrightharpoons Ar^+ + e^-$	7.48e + 11	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	431	$_{ m ti}$	$C_2 \leftrightharpoons C_2^+ + e^-$	9.18e-09	0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	432	ti	$C_2 \leftrightharpoons C_2^+ + e^-$	$2.22e{+}11$	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	433	$_{ m ti}$		1.83e-09	0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	434	$_{ m ti}$	$CH \leftrightharpoons CH^+ + e^-$	$4.41e{+10}$	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	435	$_{ m ti}$	$CN \leftrightharpoons CN^+ + e^-$	1.17e-08	0.50	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	436	$_{ m ti}$	$CN \leftrightharpoons CN^+ + e^-$	$2.81e{+11}$	-0.50	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	437	$_{ m ti}$		1.45 e - 08	0.50	0*	116
440 ti Fe \rightleftharpoons Fe ⁺ + e ⁻ 2.25e+12 -0.50 0* 441 ti H ₂ \rightleftharpoons H ₂ ⁺ + e ⁻ 4.25e-11 0.50 0* 116 442 ti H ₂ \rightleftharpoons H ₂ ⁺ + e ⁻ 1.03e+09 -0.50 0*	438	$_{ m ti}$	$CO \leftrightharpoons CO^+ + e^-$	$3.53e{+}11$	-0.50	0*	
441 ti $H_2 = H_2^+ + e^-$ 4.25e-11 0.50 0* 116 442 ti $H_2 = H_2^+ + e^-$ 1.03e+09 -0.50 0* ···	439	$_{ m ti}$	$Fe \leftrightharpoons Fe^+ + e^-$	9.33e-08	0.50	0*	116
442 ti $H_2 = H_2^{+} + e^{-}$ 1.03e+09 -0.50 0* ···	440	$_{ m ti}$	$Fe \leftrightharpoons Fe^+ + e^-$	$2.25e{+}12$	-0.50	0*	
	441	$_{ m ti}$	$H_2 \leftrightharpoons H_2^+ + e^-$	4.25e-11	0.50	0*	116
443 ti $HN = HN^+ + e^-$ 2.72e-09 0.50 0* 116	442	$_{ m ti}$	$H_2 \leftrightharpoons H_2^+ + e^-$	1.03e + 09	-0.50	0*	
	443	$_{ m ti}$	$HN \leftrightharpoons HN^+ + e^-$	2.72e-09	0.50	0*	116
444 ti $HN = HN^+ + e^-$ 6.57e+10 -0.50 0* ···	444	$_{ m ti}$	$HN \leftrightharpoons HN^+ + e^-$	6.57e + 10	-0.50	0*	
445 ti $HO = HO^+ + e^-$ 3.87e-09 0.50 0* 116	445	ti	$HO \leftrightharpoons HO^+ + e^-$	3.87e-09	0.50	0*	116
446 ti $HO = HO^+ + e^-$ 9.35e+10 -0.50 0*	446	$_{ m ti}$		9.35e + 10	-0.50	0*	
447 ti $He = He^+ + e^-$ 4.25e-11 0.50 0* 116	447	ti		4.25e-11	0.50	0*	116
448 ti $\text{He} \leftrightharpoons \text{He}^+ + e^ 1.03\text{e} + 09 - 0.50 0^* \cdots$	448	$_{ m ti}$		1.03e + 09	-0.50	0*	
449 ti $Mg = Mg^+ + e^-$ 9.18e-09 0.50 0* 116	449	ti		9.18e-09	0.50	0*	116
450 ti $Mg = Mg^{+} + e^{-}$ 2.22e+11 -0.50 0* ···	450	ti		$2.22e{+}11$	-0.50	0*	
451 ti $N_2 = N_2^+ + e^-$ 1.45e-08 0.50 0* 116	451	ti	$N_2 \leftrightharpoons N_2^+ + e^-$	1.45 e-08	0.50	0*	116

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
452	ti	$N_2 \leftrightharpoons N_2^+ + e^-$	3.53e+11	-0.50	0*	
453	ti	$NO = NO^+ + e^-$	1.80e-08	0.50	0*	116
454	$_{ m ti}$	$NO = NO^+ + e^-$	4.32e + 11	-0.50	0*	
455	ti	$O_2 \leftrightharpoons O_2^+ + e^-$	2.18e-08	0.50	0*	116
456	$_{ m ti}$	$O_2 \leftrightharpoons O_2^+ + e^-$	$5.26e{+}11$	-0.50	0*	
457	$_{ m ti}$	$Si = Si^+ + e^-$	1.45 e - 08	0.50	0*	116
458	$_{ m ti}$	$Si = Si^+ + e^-$	$3.53e{+}11$	-0.50	0*	
459	ti	$Ti \leftrightharpoons Ti^+ + e^-$	5.65 e - 08	0.50	0*	116
460	ti	$Ti \leftrightharpoons Ti^+ + e^-$	1.37e + 12	-0.50	0*	
461	$_{ m ti}$	$C_2H \leftrightharpoons C_2H^+ + e^-$	1.17e-08	0.50	0*	116
462	$_{ m ti}$	$C_2H \leftrightharpoons C_2H^+ + e^-$	$2.81e{+11}$	-0.50	0*	
463	$_{ m ti}$	$C_2N \leftrightharpoons C_2N^+ + e^-$	3.64e-08	0.50	0*	116
464	ti	$C_2N \leftrightharpoons C_2N^+ + e^-$	$8.80e{+11}$	-0.50	0*	
465	ti	$C_2O \leftrightharpoons C_2O^+ + e^-$	4.25 e-08	0.50	0*	116
466	ti	$C_2O \leftrightharpoons C_2O^+ + e^-$	1.03e + 12	-0.50	0*	
467	ti	$CH_2 \leftrightharpoons CH_2^+ + e^-$	2.72e-09	0.50	0*	116
468	ti	$CH_2 \leftrightharpoons CH_2^+ + e^-$	6.57e + 10	-0.50	0*	
469	$_{ m ti}$	$CH_3 \leftrightharpoons CH_3^+ + e^-$	3.87e-09	0.50	0*	116
470	$_{ m ti}$	$CH_3 \leftrightharpoons CH_3^+ + e^-$	$9.35e{+}10$	-0.50	0*	
471	ti	$CH_4 \leftrightharpoons CH_4^+ + e^-$	5.31e-09	0.50	0*	116
472	$_{ m ti}$	$CH_4 \leftrightharpoons CH_4^+ + e^-$	$1.28e{+11}$	-0.50	0*	
473	$_{ m ti}$	$HCN \leftrightharpoons CHN^+ + e^-$	1.45 e - 08	0.50	0*	116
474	$_{ m ti}$	$HCN \leftrightharpoons CHN^+ + e^-$	$3.53e{+}11$	-0.50	0*	
475	$_{ m ti}$	$CHO \leftrightharpoons CHO^+ + e^-$	1.80e-08	0.50	0*	116
476	ti	$CHO \leftrightharpoons CHO^+ + e^-$	$4.32e{+11}$	-0.50	0*	
477	$_{ m ti}$	$CN_2 \leftrightharpoons CN_2^+ + e^-$	4.25 e - 08	0.50	0*	116
478	ti	$CN_2 \leftrightharpoons CN_2^+ + e^-$	1.03e + 12	-0.50	0*	
479	ti	$CNO \leftrightharpoons CNO^+ + e^-$	4.91e-08	0.50	0*	116
480	ti	$CNO \leftrightharpoons CNO^+ + e^-$	$1.19e{+12}$	-0.50	0*	
481	$_{ m ti}$	$CO_2 \leftrightharpoons CO_2^+ + e^-$	5.65 e - 08	0.50	0*	116
482	$_{ m ti}$	$CO_2 \leftrightharpoons CO_2^+ + e^-$	1.37e + 12	-0.50	0*	
483	$_{ m ti}$	$FeO = FeO^+ + e^-$	2.09e-07	0.50	0*	116
484	$_{ m ti}$	$FeO = FeO^+ + e^-$	5.04e + 12	-0.50	0*	
485	$_{ m ti}$	$H_2N \leftrightharpoons H_2N^+ + e^-$	3.87e-09	0.50	0*	116
486	$_{ m ti}$	$H_2N \leftrightharpoons H_2N^+ + e^-$	$9.35e{+}10$	-0.50	0*	
487	ti	$H_2O \leftrightharpoons H_2O^+ + e^-$	5.31e-09	0.50	0*	116
488	ti	$H_2O \leftrightharpoons H_2O^+ + e^-$	$1.28e{+11}$	-0.50	0*	
489	ti	$H_3N \leftrightharpoons H_3N^+ + e^-$	5.31e-09	0.50	0*	116
490	ti	$H_3N \leftrightharpoons H_3N^+ + e^-$	$1.28e{+11}$	-0.50	0*	
491	ti	$HN_2 \leftrightharpoons HN_2^+ + e^-$	1.80e-08	0.50	0*	116
492	ti	$HN_2 \leftrightharpoons HN_2^+ + e^-$	$4.32e{+11}$	-0.50	0*	

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
493	ti	$HNO = HNO^+ + e^-$	2.18e-08	0.50	0*	116
494	$_{ m ti}$	$HNO \leftrightharpoons HNO^+ + e^-$	$5.26e{+11}$	-0.50	0*	
495	$_{ m ti}$	$HO_2 \leftrightharpoons HO_2^+ + e^-$	2.61e-08	0.50	0*	116
496	$_{ m ti}$	$HO_2 \leftrightharpoons HO_2^+ + e^-$	6.30e + 11	-0.50	0*	
497	$_{ m ti}$	$MgO = MgO^+ + e^-$	4.25 e-08	0.50	0*	116
498	$_{ m ti}$	$MgO \leftrightharpoons MgO^+ + e^-$	1.03e + 12	-0.50	0*	
499	$_{ m ti}$	$N_2O \leftrightharpoons N_2O^+ + e^-$	5.65 e - 08	0.50	0*	116
500	$_{ m ti}$	$N_2O \leftrightharpoons N_2O^+ + e^-$	1.37e + 12	-0.50	0*	
501	$_{ m ti}$	$NO_2 \leftrightharpoons NO_2^+ + e^-$	6.46 e - 08	0.50	0*	116
502	$_{ m ti}$	$NO_2 \leftrightharpoons NO_2^+ + e^-$	1.56e + 12	-0.50	0*	
503	$_{ m ti}$	$SiH = SiH^{+} + e^{-}$	1.80e-08	0.50	0*	116
504	$_{ m ti}$	$SiH \leftrightharpoons SiH^+ + e^-$	$4.32e{+11}$	-0.50	0*	
505	$_{ m ti}$	$SiO \leftrightharpoons SiO^+ + e^-$	5.65 e - 08	0.50	0*	116
506	$_{ m ti}$	$SiO \leftrightharpoons SiO^+ + e^-$	1.37e + 12	-0.50	0*	
507	$_{ m ti}$	$TiO \leftrightharpoons TiO^+ + e^-$	1.43e-07	0.50	0*	116
508	$_{ m ti}$	$TiO \leftrightharpoons TiO^+ + e^-$	3.46e + 12	-0.50	0*	
509	$_{ m ti}$	$C_2H_2 \leftrightharpoons C_2H_2^+ + e^-$	1.45 e - 08	0.50	0*	116
510	$_{ m ti}$	$C_2H_2 \leftrightharpoons C_2H_2^+ + e^-$	$3.53e{+}11$	-0.50	0*	
511	$_{ m ti}$	$C_2H_3 \leftrightharpoons C_2H_3^+ + e^-$	1.80e-08	0.50	0*	116
512	$_{ m ti}$	$C_2H_3 \leftrightharpoons C_2H_3^+ + e^-$	$4.32e{+11}$	-0.50	0*	
513	$_{ m ti}$	$C_2H_4 \leftrightharpoons C_2H_4^+ + e^-$	2.18e-08	0.50	0*	116
514	ti	$C_2H_4 \leftrightharpoons C_2H_4^+ + e^-$	5.26e + 11	-0.50	0*	
515	ti	$C_2H_5 \leftrightharpoons C_2H_5^+ + e^-$	2.61e-08	0.50	0*	116
516	ti	$C_2H_5 \leftrightharpoons C_2H_5^+ + e^-$	6.30e + 11	-0.50	0*	
517	ti	$C_2H_6 \leftrightharpoons C_2H_6^+ + e^-$	3.10e-08	0.50	0*	116
518	ti	$C_2H_6 \leftrightharpoons C_2H_6^+ + e^-$	7.48e + 11	-0.50	0*	
519	ti	$NCCN \leftrightharpoons C_2 N_2^+ + e^-$	9.33e-08	0.50	0*	116
520	ti	$NCCN \leftrightharpoons C_2N_2^+ + e^-$	2.25e + 12	-0.50	0*	
521	ti	$CH_2O \leftrightharpoons CH_2\tilde{O}^+ + e^-$	2.18e-08	0.50	0*	116
522	$_{ m ti}$	$CH_2O \leftrightharpoons CH_2O^+ + e^-$	5.26e + 11	-0.50	0*	
523	$_{ m ti}$	$CH_3N \leftrightharpoons CH_3N^+ + e^-$	2.18e-08	0.50	0*	116
524	$_{ m ti}$	$CH_3N \leftrightharpoons CH_3N^+ + e^-$	5.26e + 11	-0.50	0*	
525	$_{ m ti}$	$CH_3O \leftrightharpoons CH_3O^+ + e^-$	2.61e-08	0.50	0*	116
526	$_{ m ti}$	$CH_3O \leftrightharpoons CH_3O^+ + e^-$	6.30e + 11	-0.50	0*	
527	ti	$CH_3OH \leftrightharpoons CH_4O^+ + e^-$	3.10e-08	0.50	0*	116
528	ti	$CH_3OH \leftrightharpoons CH_4O^+ + e^-$	7.48e + 11	-0.50	0*	
529	ti	$CH_5N \leftrightharpoons CH_5N^+ + e^-$	3.10e-08	0.50	0*	116
530	ti	$CH_5N \leftrightharpoons CH_5N^+ + e^-$	7.48e + 11	-0.50	0*	
531	ti	$HNCO \leftrightharpoons CHNO^+ + e^-$	5.65 e-08	0.50	0*	116
532	ti	$HNCO \leftrightharpoons CHNO^+ + e^-$	1.37e + 12	-0.50	0*	
533	ti	$FeO_2 = FeO_2^+ + e^-$	3.94 e-07	0.50	0*	116

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
534	ti	$FeO_2 \leftrightharpoons FeO_2^+ + e^-$	9.51e + 12	-0.50	0*	
535	$_{ m ti}$	$H_2O_2 \leftrightharpoons H_2O_2^+ + e^-$	3.10e-08	0.50	0*	116
536	$_{ m ti}$	$H_2O_2 \leftrightharpoons H_2O_2^+ + e^-$	7.48e + 11	-0.50	0*	
537	$_{ m ti}$	$HNO_2 \leftrightharpoons HNO_2^+ + e^-$	7.34e-08	0.50	0*	116
538	$_{ m ti}$	$HNO_2 \leftrightharpoons HNO_2^+ + e^-$	1.77e + 12	-0.50	0*	
539	$_{ m ti}$	$MgHO \leftrightharpoons MgHO^+ + e^-$	4.91e-08	0.50	0*	116
540	ti	$MgHO \leftrightharpoons MgHO^+ + e^-$	$1.19e{+12}$	-0.50	0*	
541	$_{ m ti}$	$MgO_2 \leftrightharpoons MgO_2^+ + e^-$	1.17e-07	0.50	0*	116
542	$_{ m ti}$	$MgO_2 \leftrightharpoons MgO_2^+ + e^-$	$2.81e{+12}$	-0.50	0*	
543	$_{ m ti}$	$SiH_2 \leftrightharpoons SiH_2^+ + e^-$	2.18e-08	0.50	0*	116
544	$_{ m ti}$	$SiH_2 \leftrightharpoons SiH_2^{+} + e^{-}$	$5.26e{+11}$	-0.50	0*	
545	$_{ m ti}$	$SiH_3 \leftrightharpoons SiH_3^+ + e^-$	2.61e-08	0.50	0*	116
546	ti	$SiH_3 \leftrightharpoons SiH_3^+ + e^-$	6.30e + 11	-0.50	0*	
547	$_{ m ti}$	$SiH_4 \leftrightharpoons SiH_4^+ + e^-$	3.10e-08	0.50	0*	116
548	$_{ m ti}$	$SiH_4 \leftrightharpoons SiH_4^+ + e^-$	7.48e + 11	-0.50	0*	
549	ti	$CH_2CN \leftrightharpoons C_2H_2N^+ + e^-$	4.91e-08	0.50	0*	116
550	$_{ m ti}$	$CH_2CN \leftrightharpoons C_2H_2N^+ + e^-$	1.19e + 12	-0.50	0*	
551	$_{ m ti}$	$C_2H_2O \leftrightharpoons C_2H_2O^+ + e^-$	5.65e-08	0.50	0*	116
552	ti	$C_2H_2O \leftrightharpoons C_2H_2O^+ + e^-$	1.37e + 12	-0.50	0*	
553	ti	$C_2H_3N \leftrightharpoons C_2H_3N^+ + e^-$	5.65 e-08	0.50	0*	116
554	ti	$C_2H_3N \leftrightharpoons C_2H_3N^+ + e^-$	1.37e + 12	-0.50	0*	
555	ti	$C_2H_3O \leftrightharpoons C_2H_3O^+ + e^-$	6.46 e - 08	0.50	0*	116
556	ti	$C_2H_3O \leftrightharpoons C_2H_3O^+ + e^-$	1.56e + 12	-0.50	0^{*}	
557	ti	$C_2H_4O \leftrightharpoons C_2H_4O^+ + e^-$	7.34e-08	0.50	0^{*}	116
558	$_{ m ti}$	$C_2H_4O \leftrightharpoons C_2H_4O^+ + e^-$	1.77e + 12	-0.50	0*	
559	$_{ m ti}$	$CH_2NCH_3 \leftrightharpoons C_2H_5N^+ + e^-$	7.34e-08	0.50	0*	116
560	$_{ m ti}$	$CH_2NCH_3 \leftrightharpoons C_2H_5N^+ + e^-$	1.77e + 12	-0.50	0*	
561	$_{ m ti}$	$CH_3CH_2O \leftrightharpoons C_2H_5O^+ + e^-$	8.30e-08	0.50	0*	116
562	$_{ m ti}$	$CH_3CH_2O \leftrightharpoons C_2H_5O^+ + e^-$	2.00e + 12	-0.50	0*	
563	ti	$C_2H_5OH \leftrightharpoons C_2H_6O^+ + e^-$	9.33e-08	0.50	0*	116
564	ti	$C_2H_5OH \leftrightharpoons C_2H_6O^+ + e^-$	$2.25e{+}12$	-0.50	0*	• • •
565	ti	$CH_2O_2 \leftrightharpoons CH_2O_2^+ + e^-$	7.34e-08	0.50	0*	116
566	$_{ m ti}$	$CH_2O_2 \leftrightharpoons CH_2O_2^+ + e^-$	1.77e + 12	-0.50	0*	
567	$_{ m ti}$	$HCOOH \leftrightharpoons CH_2O_2^+ + e^-$	7.34e-08	0.50	0*	116
568	$_{ m ti}$	$HCOOH = CH_2O_2^+ + e^-$	1.77e + 12		0*	
569	$_{ m ti}$	$CH_2OH = CH_2OH^+ + e^-$	2.61e-08	0.50	0*	116
570	ti	$CH_2OH \leftrightharpoons CH_2OH^+ + e^-$	6.30e + 11	-0.50	0*	
571	$_{ m ti}$	$CH_3O_2 \leftrightharpoons CH_3O_2^+ + e^-$	8.30e-08	0.50	0*	116
572	ti	$CH_3O_2 \leftrightharpoons CH_3O_2^+ + e^-$	2.00e + 12	-0.50	0*	
573	ti	$Na = Na^+ + e^-$	8.49e + 05	0.77	0*	116
574	$_{ m ti}$	$Na = Na^+ + e^-$	2.48e + 12	-0.23	0*	

Table 6—Continued

$\begin{array}{cccccccccccccccccccccccccccccccccccc$			TABLE 6—Cor	ıtınuea			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	#	Type	Reaction	α	β	γ	Ref
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	575	ti	$K \leftrightharpoons K^+ + e^-$	8.49e + 05	0.77	0*	116
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	576	ti	$K \leftrightharpoons K^+ + e^-$	2.48e + 12	-0.23	0*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	577	2n	$C + CN \leftrightharpoons C_2 + N$	6.64e - 11	0.00	0	118
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	578	2n	$CH + H \leftrightharpoons C + H_2$	1.30e-10	0.00	80	163
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	579	2n	$C + N_2 \leftrightharpoons CN + N$	8.70e-11	0.00	22600	33
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	580	2n	$C + NO \leftrightharpoons CO + N$	3.49e-11	-0.02	0	120
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	581	2n	$C + O_2 \leftrightharpoons CO + O$	1.99e-10	0.00	2010	119
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	582	2n	$C + CH_2 \leftrightharpoons CH + CH$	2.69e-12	0.00	23500	121
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	583	2n	$C + H_2N \leftrightharpoons CH + HN$	9.61e-13	0.00	10500	121
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	584	2n	$C + H_2O \leftrightharpoons CH + HO$	1.30e-12	0.00	19800	121
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	585	2n	$C + NCCN \leftrightharpoons CN + C_2N$	3.01e-11	0.00	0	122
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	586	2n	$H + HN \leftrightharpoons H + H + N$	4.02e-10	-0.20	27300	123
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	587	2n	$H + HN \leftrightharpoons H_2 + N$	2.14e-12	1.55	120	124
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	588	2n	$H + HO \leftrightharpoons H_2 + O$	6.86e-14	2.80	1950	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	589	2n	$H + N_2 \leftrightharpoons HN + N$	5.27e-10	0.50	74500	123
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	590	2n	$H + NO \leftrightharpoons HN + O$	9.30e-10	-0.10	35200	125
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	591	2n	$H + NO \leftrightharpoons HO + N$	3.60e-10	0.00	24900	33
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	592	2n	$H + O_2 \leftrightharpoons HO + O$	6.73e-10	-0.59	8150	126
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	593	2n	$H + C_2H \leftrightharpoons H_2 + C_2$	5.99e-11	0.00	14200	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	594	2n	$H + C_2O \leftrightharpoons CO + CH$	2.19e-11	0.00	0	127
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	595	2n	$H + CH_2 \leftrightharpoons H_2 + CH$	2.60e-10	0.00	0	5
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	596	2n	$H + HCN \leftrightharpoons HNC + H$	3.53e-13	0.00	0	128
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	597	2n	$H + HCN \leftrightharpoons CN + H_2$	6.19e-10	0.00	12500	18
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	598	2n	$H + CHO \leftrightharpoons O + CH_2$	6.61e-11	0.00	51600	129
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	599	2n	$H + CHO \leftrightharpoons CO + H_2$	1.50e-10	0.00	0	5
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	600	2n	$H + NCO \leftrightharpoons CO + HN$	8.90e-11	0.00	0	3
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	601	2n	$H + NCO \leftrightharpoons HCN + O$	1.86e-11	0.90	2920	3
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	602	2n	$H + CO_2 \leftrightharpoons CO + HO$	2.51e-10	0.00	13400	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	603	2n	$H + H_2N \leftrightharpoons H_2 + HN$	1.05e-10	0.00	4450	130
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	604	2n	$H + H_2O \leftrightharpoons H_2 + HO$	6.82e-12	1.60	9720	5
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	605	2n	$H + HNO \leftrightharpoons H_2N + O$	1.05e-09	-0.30	14700	125
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	606	2n	$H + HNO \leftrightharpoons HO + HN$	2.41e-09	-0.50	9010	125
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	607	2n	$H + HNO \leftrightharpoons H_2 + NO$	5.63e-11	0.62	179	131
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	608	2n	$H + HO_2 \leftrightharpoons H_2O + O$	6.55e-12	1.47	6990	132
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	609	2n	$H + HO_2 \leftrightharpoons HO + HO$	5.50e-11	0.88	0	132
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	610	2n	$H + HO_2 \leftrightharpoons H_2 + O_2$	5.60 e-12	1.72	0	132
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	611	2n	$H + N_2O \leftrightharpoons O + HN_2$	2.18e-08	-1.06	23800	133
$514 2n H + NO_2 = HO + NO 1.47e-10 0.00 0 134$	612	2n	$H + N_2O \leftrightharpoons NO + HN$	5.03e-07	-2.16	18600	133
-	613	2n	$H + N_2O \leftrightharpoons HO + N_2$	1.60e-10	0.00	7600	18
315 2n H + O ₃ \rightleftharpoons HO + O ₂ 2.72e-11 0.75 0 135	614	2n	$H + NO_2 \leftrightharpoons HO + NO$	1.47e-10	0.00	0	134
	615	2n	$H + O_3 \leftrightharpoons HO + O_2$	2.72e-11	0.75	0	135

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
616	2n	$H + C_2H_2 \leftrightharpoons H_2 + C_2H$	2.49e-10	1.30	15400	373
617	2n	$H + NCCN \leftrightharpoons CN + HCN$	5.25 e-10	0.00	4030	136
618	2n	$H + CH_3 \leftrightharpoons H_2 + CH_2$	1.00e-10	0.00	7600	5
619	2n	$H + CH_2O \leftrightharpoons H_2 + CHO$	2.14e-12	1.62	1090	33
620	2n	$H + HNCO \leftrightharpoons H_2 + NCO$	2.67e-13	2.50	6690	137
621	2n	$H + HNCO = CO + H_2N$	5.99e-13	1.70	1910	137
622	2n	$H + HOCN \leftrightharpoons H_2 + NCO$	1.66e-12	0.00	0	138
623	2n	$H + HOCN = CN + H_2O$	1.66e-12	0.00	0	138
624	2n	$H + H_3N \leftrightharpoons H_2 + H_2N$	6.54 e-13	2.76	5170	139
625	2n	$H + H_2N_2 \leftrightharpoons HN_2 + H_2$	4.53e-13	2.63	0	140
626	2n	$H + H_2O_2 \leftrightharpoons HO + H_2O$	4.00e-11	0.00	1800	7
627	2n	$H + H_2O_2 \leftrightharpoons H_2 + HO_2$	8.00e-11	0.00	4000	7
628	2n	$H + HNO_2 \leftrightharpoons H_2O + NO$	6.39e-13	1.89	1940	141
629	2n	$H + HNO_2 \leftrightharpoons HO + HNO$	1.26e-11	0.86	2500	141
630	2n	$H + HNO_2 \leftrightharpoons H_2 + NO_2$	2.27e-12	1.55	3330	141
631	2n	$H + NO_3 \rightleftharpoons HO + NO_2$	1.10e-10	0.00	0	142
632	2n	$H + C_2H_3 \leftrightharpoons C_2H_2 + H_2$	2.03e-10	-1.00	0	21
633	2n	$H + C_2H_2O \rightleftharpoons CO + CH_3$	4.99e-12	1.45	1400	143
634	2n	$H + CH_4 \leftrightharpoons H_2 + CH_3$	5.94e-13	3.00	4050	5
635	2n	$H + CH_3O \rightleftharpoons CH_2O + H_2$	3.14e-10	-0.58	855	89
636	2n	$H + CH_2OH \Rightarrow CH_3 + HO$	1.60e-10	0.00	0	145
637	2n	$H + CH_2OH \leftrightharpoons CH_2O + H_2$	1.00e-11	0.00	0	145
638	2n	$H + CH_2N_2 \leftrightharpoons CH_3 + N_2$	1.60e-11	0.00	0	146
639	2n	$H + HNO_3 \leftrightharpoons H_2O + NO_2$	1.39e-14	3.29	3160	147
640	2n	$H + HNO_3 \leftrightharpoons H_2 + NO_3$	5.65e-12	1.53	8250	147
641	2n	$H + C_2H_4 \leftrightharpoons H_2 + C_2H_3$	5.08e-12	1.93	6520	148
642	2n	$H + CH_3CN \leftrightharpoons HCN + CH_3$	3.39e-12	0.00	3950	149
643	2n	$H + CH_3CN \leftrightharpoons CN + CH_4$	1.66e-13	0.00	1530	149
644	2n	$H + C_2H_3O \leftrightharpoons CH_3 + CHO$	3.32e-11	0.00	0	150
645	2n	$H + C_2H_2O_2 \leftrightharpoons CO + H_2 + CHO$	8.97e-11	0.00	0	151
646	2n	$H + CH_3OH \Rightarrow CH_3 + H_2O$	9.41e-09	0.00	12400	Est
647	2n	$H + CH_3OH = CH_2OH + H_2$	2.42e-12	2.00	2270	152
648	2n	$H + CH_3OH = CH_3O + H_2$	6.64e-11	0.00	3070	45
649	2n	$H + H_4N_2 \leftrightharpoons NH_2NH + H_2$	1.17e-11	0.00	1260	153
650	2n	$H + H_2NNO_2 \leftrightharpoons HNO + NO + H_2$	1.66e-12		0	14
651	2n	$H + C_2H_5 \leftrightharpoons CH_3 + CH_3$	2.00e-10	0.00	0	144
652	2n	$H + C_2H_5 \leftrightharpoons C_2H_4 + H_2$	3.01e-12	0.00	0	7
653	2n	$H + C_2H_4O \leftrightharpoons C_2H_4 + H_2$ $H + C_2H_4O \leftrightharpoons C_2H_3O + H_2$	5.27e-13	2.58	614	154
654	2n	$H + C_2H_4O \Rightarrow CH_2CHO + H_2$	2.12e-13	3.10	2620	154
(),) +						
655	2n	$H + C_2H_4O \leftrightharpoons CH_3 + CO + H_2$	4.88e-13	2.75	486	154

Table 6—Continued

		TABLE 0—Continue	<i>u</i>			
#	Type	Reaction	α	β	γ	Ref
657	2n	$H + Oxyrane = C_2H_4O + H$	9.22e-11	0.00	5510	68
658	2n	$H + Oxyrane = C_2H_4 + HO$	1.58e-13	0.00	2520	156
659	2n	$H + Oxyrane = C_2H_3 + H_2O$	8.30e-15	0.00	2520	156
660	2n	$H + Oxyrane = cyc-C_2H_3O + H_2$	3.32e-11	0.00	4180	156
661	2n	$H + CH_3NO_2 \leftrightharpoons CH_3 + HNO_2$	5.28e-09	0.00	7920	157
662	2n	$H + CH_3ONO \leftrightharpoons CH_3OH + NO$	2.03e-13	0.00	665	158
663	2n	$H + C_2H_6 \leftrightharpoons C_2H_5 + H_2$	1.22e-11	1.50	3730	144
664	2n	$H + C_2H_5OH \leftrightharpoons C_2H_5 + H_2O$	9.80e-13	0.00	1740	159
665	2n	$N + CH \leftrightharpoons C + HN$	3.02e-11	0.65	1210	160
666	2n	$N + CH \leftrightharpoons CN + H$	1.66e-10	0.00	0	161
667	2n	N + CO = CN + O	3.84e-09	0.00	36000	162
668	2n	$N + HO \leftrightharpoons HN + O$	1.88e-11	0.10	10700	125
669	2n	$N + NO \leftrightharpoons N_2 + O$	3.40e-11	0.00	0	164
670	2n	$N + O_2 \leftrightharpoons NO + O$	3.44e-12	1.18	4000	165
671	2n	$N + C_2N \leftrightharpoons CN + CN$	1.00e-10	0.00	0	122
672	2n	$N + C_2O \leftrightharpoons CN + CO$	5.50 e-10	0.00	0	166
673	2n	$N + CH_2 \leftrightharpoons CH + HN$	9.96e-13	0.00	20500	121
674	2n	$N + NCO = CO + N_2$	3.30e-11	0.00	0	5
675	2n	$N + NCO \leftrightharpoons CN + NO$	1.66e-12	0.00	0	167
676	2n	$N + CO_2 \leftrightharpoons CO + NO$	3.20e-13	0.00	1710	168
677	2n	$N + H_2N \leftrightharpoons HN + HN$	2.99e-13	0.00	7600	121
678	2n	$N + H_2O \leftrightharpoons HO + HN$	6.03e-11	1.20	19200	125
679	2n	$N + NO_2 \leftrightharpoons N_2O + O$	5.80e-12	0.00	0	169
680	2n	$N + N_2O \leftrightharpoons N_2 + NO$	1.50e-11	0.00	51	169
681	2n	$N + O_3 \leftrightharpoons O_2 + NO$	1.00e-16	0.00	0	170
682	2n	$N + HCCN \leftrightharpoons NCCN + H$	6.00 e-15	0.00	0	171
683	2n	$N + CH_3 \leftrightharpoons H_2CN + H$	1.18e-10	0.00	0	172
684	2n	$N + CH_3 \leftrightharpoons HCN + H + H$	3.33e-13	0.00	0	173
685	2n	$N + HNCO \leftrightharpoons HN + NCO$	3.85 e-05	0.00	26500	174
686	2n	$N + C_2H_3 \leftrightharpoons CH_2CN + H$	7.70e-11	0.00	0	175
687	2n	$N + CH_4 \leftrightharpoons HCN + H_2 + H$	2.51e-14	0.00	0	176
688	2n	$N + C_2H_4 \leftrightharpoons HCN + CH_3$	2.66e-14	0.00	352	177
689	2n	$N + CH_3CN \leftrightharpoons HCN + HCN + H$	2.27e-15	0.00	813	178
690	2n	$N + CH_3OH \leftrightharpoons CH_3 + HNO$	3.99e-10	0.00	4330	179
691	2n	$N + C_2H_4O \leftrightharpoons HCN + CHO + H_2$	1.99e-14	0.00	0	180
692	2n	$N + C_2H_5OH \leftrightharpoons C_2H_5 + HNO$	3.32e-10	0.00	4210	179
693	2n	$O + C_2 \leftrightharpoons CO + C$	5.99e-10	0.00	0	181
694	2n	$O + CH \leftrightharpoons HO + C$	2.52e-11	0.00	2380	182
695	2n	$O + CH \leftrightharpoons CO + H$	1.02e-10	0.00	914	182
696	2n	$O + CN \leftrightharpoons NO + C$	5.37e-11	0.00	13700	120
697	2n	$O + C_2H \leftrightharpoons CO + CH$	1.69e-11	0.00	0	5

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
698	2n	$O + C_2N \leftrightharpoons CN + CO$	5.99e-12	0.00	0	166
699	2n	$O + C_2O \leftrightharpoons CO + CO$	8.60e-11	0.00	0	127
700	2n	$O + CH_2 \leftrightharpoons CO + H + H$	1.33e-10	0.00	0	183
701	2n	$O + CH_2 \leftrightharpoons CO + H_2$	6.64 e-11	0.00	0	41
702	2n	$O + HCN \leftrightharpoons CO + HN$	8.88e-13	1.21	3820	18
703	2n	$O + HCN \leftrightharpoons CN + HO$	3.65e-11	1.58	13300	18
704	2n	$O + HNC \leftrightharpoons CO + HN$	7.64e-12	0.00	1100	14
705	2n	$O + CHO \leftrightharpoons CO + HO$	5.00e-11	0.00	0	5
706	2n	$O + CHO \leftrightharpoons CO_2 + H$	5.00e-11	0.00	0	5
707	2n	$O + NCN \leftrightharpoons CO + N_2$	2.22e-16	2.32	0	184
708	2n	$O + NCN \leftrightharpoons NCO + N$	2.26e-11	0.18	0	184
709	2n	$O + NCO \leftrightharpoons CO + NO$	7.51e-11	0.00	0	3
710	2n	$O + NCO \leftrightharpoons CN + O_2$	4.05e-10	-1.43	3400	3
711	2n	$O + CO_2 \leftrightharpoons CO + O_2$	1.41e-11	0.00	22100	185
712	2n	$O + H_2N \leftrightharpoons HO + HN$	1.16e-11	0.00	0	125
713	2n	$O + H_2N \leftrightharpoons H_2 + NO$	8.30e-12	0.00	0	125
714	2n	$O + H_2O \leftrightharpoons HO + HO$	6.68e-13	2.60	7640	186
715	2n	$O + H_2O \leftrightharpoons H_2 + O_2$	4.48e-12	0.97	35300	187
716	2n	$O + HNO \leftrightharpoons HO + NO$	5.99e-11	0.00	0	18
717	2n	$O + HO_2 \leftrightharpoons HO + O_2$	1.36e-11	0.75	0	135
718	2n	$O + N_2O \leftrightharpoons NO + NO$	1.52e-10	0.00	14000	188
719	2n	$O + N_2O \leftrightharpoons N_2 + O_2$	6.13e-12	0.00	8020	188
720	2n	$O + NO_2 \leftrightharpoons NO + O_2$	6.51e-12	0.00	0	169
721	2n	$O + O_3 \leftrightharpoons O_2 + O_2$	2.23e-12	0.75	1580	135
722	2n	$O + C_2H_2 \leftrightharpoons HCCO + H$	7.14e-10	0.00	6100	189
723	2n	$O + C_2H_2 \leftrightharpoons CH_2 + CO$	3.49e-12	1.50	850	189
724	2n	$O + NCCN \leftrightharpoons CN + NCO$	4.15e-11	0.00	5500	101
725	2n	$O + CH_3 \leftrightharpoons CH_2O + H$	1.40e-10	0.00	0	5
726	2n	$O + CH_3 \leftrightharpoons CO + H_2 + H$	5.72e-11	0.00	0	190
727	2n	$O + CH_2O \leftrightharpoons CHO + HO$	1.78e-11	0.57	1390	5
728	2n	$O + CH_2O \leftrightharpoons CO + HO + H$	1.00e-10	0.00	0	191
729	2n	$O + HNCO \leftrightharpoons CO_2 + HN$	4.93e-13	1.41	4290	3
730	2n	$O + HNCO \leftrightharpoons NCO + HO$	6.61e-13	2.11	5750	3
731	2n	$O + H_3N \leftrightharpoons HO + H_2N$	1.60e-11	0.00	3670	5
732	2n	$O + H_3N \leftrightharpoons H_2O + HN$	2.98e-13	0.00	2420	Est
733	2n	$O + H_2O_2 \leftrightharpoons HO_2 + HO$	1.42e-12	2.00	2000	7
734	2n	$O + HNO_2 \leftrightharpoons HO + NO_2$	2.01e-11	0.00	3000	18
735	2n	$O + NO_3 \leftrightharpoons O_2 + NO_2$	1.70e-11	0.00	0	32
736	2n	$O + C_2H_3 \leftrightharpoons C_2H_2O + H$	1.60e-10	0.00	0	7
737	2n	$O + C_2H_3 \leftrightharpoons C_2H_2 + HO$	5.50e-12	0.20	0	192
738	2n	$O + CH_4 \leftrightharpoons CH_3 + HO$	5.63e-10	0.00	6230	193

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
739	2n	$O + CH_4 \leftrightharpoons CH_2O + H_2$	7.51e-12	0.00	6230	Est
740	2n	$O + CH_3O \leftrightharpoons CH_2O + HO$	1.00e-11	0.00	0	7
741	2n	$O + CH_3O \leftrightharpoons CH_3 + O_2$	3.55e-11	0.00	0	194
742	2n	$O + CH_2OH \leftrightharpoons CH_2O + HO$	7.01e-11	0.00	0	145
743	2n	$O + C_2H_4 \leftrightharpoons C_2H_3O + H$	6.24 e-13	0.00	0	195
744	2n	$O + C_2H_4 \leftrightharpoons C_2H_3 + HO$	2.31e-11	0.00	3620	196
745	2n	$O + C_2H_4 \leftrightharpoons CH_3 + CHO$	1.50e-12	1.55	0	7
746	2n	$O + C_2H_4 \leftrightharpoons C_2H_2O + H_2$	3.82e-14	0.00	0	33
747	2n	$O + C_2H_4 \leftrightharpoons CH_2O + CH_2$	8.30e-12	0.00	754	197
748	2n	$O + C_2H_3O \leftrightharpoons C_2H_2O + HO$	6.40 e-11	0.00	0	33
749	2n	$O + C_2H_3O \leftrightharpoons CO_2 + CH_3$	1.60e-11	0.00	0	7
750	2n	$O + CH_3OH \leftrightharpoons CH_2OH + HO$	5.71e-11	0.00	2750	198
751	2n	$O + CH_3OH \leftrightharpoons CH_3O + HO$	1.66e-11	0.00	2360	45
752	2n	$O + H_4N_2 \leftrightharpoons H_2N_2 + H_2O$	1.41e-10	0.00	603	199
753	2n	$O + C_2H_5 \leftrightharpoons H_2C_2HOH + H$	1.33e-10	0.00	0	Est
754	2n	$O + C_2H_5 \leftrightharpoons C_2H_4 + HO$	6.31e-12	0.03	0	192
755	2n	$O + C_2H_5 \leftrightharpoons CH_2O + CH_3$	2.67e-11	0.00	0	7
756	2n	$O + C_2H_4O \leftrightharpoons CH_2CHO + HO$	2.49e-11	0.00	2520	59
757	2n	$O + C_2H_4O \leftrightharpoons C_2H_3O + HO$	2.81e-11	0.00	1680	200
758	2n	$O + Oxyrane = cyc-C_2H_3O + HO$	3.17e-12	0.00	2640	201
759	2n	$O + C_2H_6 \leftrightharpoons C_2H_5 + HO$	5.11e-12	2.40	2930	202
760	2n	$O + C_2H_5OH \leftrightharpoons CH_3CHOH + HO$	1.03e-13	0.00	0	203
761	2n	$O + C_2H_5OH \leftrightharpoons CH_3CH_2O + HO$	1.23e-15	4.73	870	204
762	2n	$O + (CH_3)_2O \leftrightharpoons CH_3OCH_2 + HO$	4.68e-10	0.00	2590	205
763	2n	$CN + CN \leftrightharpoons C_2 + N_2$	2.66e-09	0.00	21700	206
764	2n	$HN + HN \leftrightharpoons N_2 + H + H$	1.16e-09	0.00	0	207
765	2n	$NO + NO \leftrightharpoons N_2 + O_2$	5.10e-10	0.50	30600	Est
766	2n	$O_3 + O_3 \leftrightharpoons O_2 + O_2 + O_2$	7.47e-12	0.00	9310	208
767	2n	$C_2 + HO = CO + CH$	8.30e-12	0.00	0	209
768	2n	$C_2 + NO = C_2O + N$	3.75e-11	0.00	4350	210
769	2n	$C_2 + NO \leftrightharpoons C_2N + O$	8.75e-11	0.00	4350	210
770	2n	$C_2 + O_2 \leftrightharpoons CO + CO$	1.10e-11	0.00	381	211
771	2n	$CH + N_2 \leftrightharpoons NCN + H$	4.06e-13	1.12	8820	212
772	2n	$CH + N_2 \leftrightharpoons HCN + N$	6.64e-13	0.00	6840	213
773	2n	$CH + NO \leftrightharpoons NCO + H$	4.40e-11	0.00	0	214
774	2n	$CH + NO \leftrightharpoons CHO + N$	1.33e-11	0.00	0	215
775	2n	$CH + NO \leftrightharpoons CO + HN$	2.00e-10	0.00	0	214
776	2n	$CH + NO \leftrightharpoons HCN + O$	1.37e-10	0.00	0	215
777	2n	$CH + NO \leftrightharpoons CN + HO$	1.40e-10	0.00	0	214
778	2n	$CH + O_2 \leftrightharpoons CHO + O$	1.66e-11	0.00	0	216
779	2n	$CH + O_2 \leftrightharpoons CO + HO$	8.30e-11	0.00	0	217

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
780	2n	$CH + H_2O \leftrightharpoons CH_2O + H$	2.82e-11	-1.22	0	218
781	2n	$CH + N_2O \leftrightharpoons HCN + NO$	7.82e-11	0.00	0	Est
782	2n	$CH + N_2O \leftrightharpoons CO + N_2 + H$	3.09e-11	0.00	0	Est
783	2n	$CH + NO_2 \leftrightharpoons CHO + NO$	1.45e-10	0.00	0	219
784	2n	$CH + CH_4 \leftrightharpoons C_2H_4 + H$	9.25 e-11	-0.90	0	220
785	2n	$CH + C_2H_4 \leftrightharpoons C_3H_4 + H$	2.84e-10	-0.31	0	Est
786	2n	$CN + HO \leftrightharpoons NCO + H$	7.01e-11	0.00	0	3
787	2n	$CN + NO \leftrightharpoons CO + N_2$	1.79e-10	0.00	4040	221
788	2n	$CN + O_2 \leftrightharpoons CO + NO$	2.42e-12	0.18	0	222
789	2n	$CN + CHO \leftrightharpoons HCN + CO$	1.00e-10	0.00	0	3
790	2n	$CN + NCO \leftrightharpoons NCN + CO$	5.18e-11	0.16	0	223
791	2n	$CN + NCO \leftrightharpoons CN_2 + CO$	3.01e-11	0.00	0	3
792	2n	$CN + H_2O \rightleftharpoons HCN + HO$	3.82e-11	0.00	6700	224
793	2n	$CN + HNO \leftrightharpoons HCN + NO$	3.01e-11	0.00	0	3
794	2n	$CN + N_2O \leftrightharpoons NCO + N_2$	2.01e-12	0.00	0	171
795	2n	$CN + N_2O \leftrightharpoons CNN + NO$	1.73e-14	2.60	1860	3
796	2n	$CN + NO_2 \leftrightharpoons NCO + NO$	4.00e-11	0.00	0	3
797	2n	$CN + NO_2 \leftrightharpoons N_2O + CO$	7.11e-12	0.00	0	225
798	2n	$CN + NO_2 \leftrightharpoons CO_2 + N_2$	5.20e-12	0.00	0	225
799	2n	$CN + C_2H_2 \leftrightharpoons HC_3N + H$	2.43e-10	0.00	0	226
800	2n	$CN + C_2H_2 \leftrightharpoons HCN + C_2H$	2.19e-10	0.00	0	227
801	2n	$CN + CH_2O \rightleftharpoons HCN + CHO$	7.01e-11	0.00	0	3
802	2n	$CN + HNCO \leftrightharpoons HCN + NCO$	2.51e-11	0.00	0	3
803	2n	$CN + HCNO \leftrightharpoons HCCN + NO$	3.95e-11	0.00	0	228
804	2n	$CN + HCNO \leftrightharpoons HCN + NCO$	1.10e-10	0.00	0	229
805	2n	$CN + H_3N \leftrightharpoons HCN + H_2N$	1.66e-11	0.00	0	101
806	2n	$CN + HNO_2 \leftrightharpoons HCN + NO_2$	2.01e-11	0.00	0	3
807	2n	$CN + C_2H_2O \leftrightharpoons HNC + HCCO$	2.37e-11	0.00	0	230
808	2n	$CN + CH_4 \leftrightharpoons HCN + CH_3$	5.11e-13	2.64	0	33
809	2n	$CN + C_2H_4 \leftrightharpoons C_3H_3N + H$	3.49e-10	0.00	0	Est
810	2n	$CN + C_2H_4 \leftrightharpoons C_2H_3 + HCN$	2.09e-10	0.00	0	227
811	2n	$CN + CH_3OH \leftrightharpoons CH_3O + HCN$	1.20e-10	0.00	0	Est
812	2n	$CN + C_2H_6 \leftrightharpoons C_2H_5 + HCN$	2.08e-11	0.22	0	231
813	2n	$CO + HNO = CO_2 + HN$	3.32e-12	0.00	6190	130
814	2n	$CO + HO_2 = CO_2 + HO$	6.46e-14	2.18	9030	232
815	2n	$CO + N_2O \leftrightharpoons CO_2 + N_2$	5.30e-13	0.00	10200	18
816	2n	$CO + NO_2 = CO_2 + NO$	1.50e-10	0.00	17000	18
817	2n	$CO + C_2H_2 \leftrightharpoons C_2H + CHO$	8.00e-10	0.00	53600	7
818	2n	$CO + CH_3 \leftrightharpoons C_2H_2 + HO$	6.31e-11	0.00	30400	233
819	2n	$CO + CH_3O = CH_3 + CO_2$	2.61e-11	0.00	5940	7
820	2n	$CO + CH_3O \leftrightharpoons CH_2O + CHO$	3.23e-13	2.28	10100	Est

Table 6—Continued

$\begin{array}{c} 221 & 2n & CO + C_2H_4 \leftrightharpoons C_2H_3 + CHO \\ 222 & 2n & H_2 + O_2 \leftrightharpoons HO + HO \\ 222 & 2n & H_2 + HNO \leftrightharpoons H_2O + HN \\ 223 & 2n & H_2 + HNO \leftrightharpoons H_2O + HN \\ 224 & 2n & H_2 + N_2O \leftrightharpoons H_2O + N_2 \\ 225 & 2n & H_2 + H_2O_2 \leftrightharpoons HO + HO + H_2 \\ 226 & 2n & H_2 + H_2O_2 \leftrightharpoons HO + HO + H_2 \\ 226 & 2n & HN + NO \leftrightharpoons HN_2 + O \\ 227 & 2n & HN + NO \leftrightharpoons HN_2 + O \\ 228 & 2n & HN + NO \leftrightharpoons HO + N_2 \\ 229 & 2n & HN + NO \leftrightharpoons HO + N_2 \\ 229 & 2n & HN + NO \leftrightharpoons HO + N_2 \\ 220 & 2n & HN + O_2 \leftrightharpoons HO + NO \\ 220 & 2n & HN + O_2 \leftrightharpoons HO + NO \\ 220 & 2n & HN + O_2 \leftrightharpoons HO + NO \\ 220 & 2n & HN + O_2 \leftrightharpoons HNO + O \\ 220 & 2n & HN + O_2 \leftrightharpoons HNO + O \\ 220 & 2n & HN + O_2 \leftrightharpoons HNO + O \\ 220 & 2n & HN + O_2 \leftrightharpoons HNO + NO \\ 220 & 2n & HN + O_2 \leftrightharpoons HNO + NO \\ 220 & 2n & HN + H_2N \leftrightharpoons H_2N_2 + H \\ 220 & 2n & HN + H_2O \leftrightharpoons H_2N + HO \\ 220 & 2n & HN + H_2O \leftrightharpoons H_2N + HO \\ 220 & 2n & HN + H_2O \leftrightharpoons H_2N + HO \\ 220 & 2n & HN + H_2O \leftrightharpoons H_2N + HO \\ 220 & 2n & HN + H_2O \leftrightharpoons H_2N + HO \\ 220 & 2n & HN + H_2O \leftrightharpoons H_2N + HO \\ 220 & 2n & HN + HO_2 \leftrightharpoons HNO + NO \\ 220 & 2n & HN + HO_2 \leftrightharpoons HNO + NO \\ 220 & 2n & HN + HO_2 \leftrightharpoons HNO + NO \\ 220 & 2n & HN + HO_2 \leftrightharpoons HNO + NO \\ 220 & 34 & 2n & HN + HO_2 \leftrightharpoons H_2N + HO \\ 230 & 2n & HN + HNCO \leftrightharpoons H_2N + HOO \\ 230 & 2n & HN + H_3N \leftrightharpoons H_2N + H_2N \\ 230 & 2n & HN + H_3N \leftrightharpoons H_2N + H_2N \\ 230 & 2n & HN + C_2H_4O \leftrightharpoons C_2H_3O + H_2N \\ 230 & 2n & HN + C_2H_4O \leftrightharpoons C_2H_3O + H_2N \\ 230 & 2n & HN + C_2H_4O \leftrightharpoons C_2H_3O + H_2N \\ 230 & 2n & HO + C_2H \leftrightharpoons CH_2 + CO \\ 240 & 2n & HO + C_2H \leftrightharpoons CH_2O + H \\ 241 & 2n & HO + HCN \leftrightharpoons HOCN + H \\ 242 & 2n & HO + HCN \leftrightharpoons HOCN + H \\ 244 & 2n & HO + HCN \leftrightharpoons HOCO + H \\ 245 & 2n & HO + HNC \leftrightharpoons H_2O + NO \\ 246 & 2n & HO + HNC \leftrightharpoons H_2O + NO \\ 247 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 248 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 249 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + HNO \leftrightharpoons H_2O + NO \\ 240 & 2n & HO + H$			TABLE 0—Continu	.cu			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	#	Type	Reaction	α	β	γ	Ref
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	821	2n	$CO + C_2H_4 \leftrightharpoons C_2H_3 + CHO$	2.51e-10	0.00	45600	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	822	2n	$H_2 + O_2 \leftrightharpoons HO + HO$	4.15e-11	0.44	34800	187
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	823	2n	$H_2 + HNO \leftrightharpoons H_2O + HN$	1.66e-10	0.00	8060	130
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	824	2n	$H_2 + N_2O \leftrightharpoons H_2O + N_2$	5.73e-12	0.50	0	234
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	825	2n	$H_2 + H_2O_2 \leftrightharpoons HO + HO + H_2$	7.04e-08	0.00	22900	235
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	826	2n	$HN + NO \leftrightharpoons HN_2 + O$	3.07e-11	0.21	5470	133
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	827	2n	$HN + NO \leftrightharpoons HO + N_2$	5.86e-12	-0.50	0	133
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	828	2n	$HN + O_2 \leftrightharpoons HNO + O$	6.79 e-14	2.00	3270	137
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	829	2n	$HN + O_2 \leftrightharpoons HO + NO$	1.09e-14	1.50	0	137
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	830	2n	$HN + H_2N \leftrightharpoons H_2N_2 + H$	1.44e-10	-0.50	0	236
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	831	2n	$HN + H_2O \leftrightharpoons H_2N + HO$	1.81e-12	1.60	14100	125
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	832	2n	$HN + NO_2 \leftrightharpoons HNO + NO$	9.50 e-12	0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	833	2n	$HN + NO_2 \leftrightharpoons N_2O + HO$	6.60 e-12	0.00	0	237
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	834	2n	$HN + HNCO \leftrightharpoons H_2N + NCO$	1.04e-11	1.82	12000	238
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	835	2n	$HN + H_3N \leftrightharpoons H_2N + H_2N$	5.25 e-10	0.00	13500	239
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	836	2n	$HN + CH_4 \leftrightharpoons CH_3 + H_2N$	1.49e-10	0.00	10100	130
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	837	2n	$HN + C_2H_4O \rightleftharpoons C_2H_3O + H_2N$	8.30e-11	0.00	5770	130
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	838	2n	$HN + C_2H_6 \leftrightharpoons C_2H_5 + H_2N$	1.16e-10	0.00	8420	130
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	839	2n	$HO + C_2H \leftrightharpoons CH_2 + CO$	3.01e-11	0.00	0	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	840	2n	$HO + C_2H \leftrightharpoons C_2H_2 + O$	3.01e-11	0.00	0	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	841	2n	$HO + CH_2 \leftrightharpoons CH_2O + H$	3.01e-11	0.00	0	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	842	2n	$HO + HCN \leftrightharpoons H_2N + CO$	1.07e-13	0.00	5890	240
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	843	2n	$HO + HCN \leftrightharpoons HOCN + H$	2.01e-11	0.00	8520	240
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	844	2n	$HO + HCN \leftrightharpoons HNCO + H$	2.84e-13	0.00	4390	240
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	845	2n	$HO + HNC \leftrightharpoons HNCO + H$	4.65e-11	0.00	1860	14
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	846	2n	$HO + CHO \leftrightharpoons H_2O + CO$	1.69e-10	0.00	0	5
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	847	2n	$HO + NCO \leftrightharpoons CHO + NO$	3.99e-13	0.00	0	241
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	848	2n	$HO + NCO \leftrightharpoons CO + NO + H$	2.99e-13	0.00	0	241
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	849	2n	$HO + HNO \leftrightharpoons H_2O + NO$	4.72e-12	0.94	0	131
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	850	2n	$HO + HO_2 \leftrightharpoons H_2O + O_2$	7.11e-11	-0.21	0	242
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	851	2n	$HO + N_2O \leftrightharpoons HNO + NO$	1.01e-17	4.33	12600	243
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	852	2n	$HO + N_2O \leftrightharpoons HO_2 + N_2$	1.03e-14	4.72	18400	243
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	853	2n	$HO + NO_2 \leftrightharpoons HO_2 + NO$	2.25e-11	0.00	3830	244
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	854	2n	$HO + O_3 \leftrightharpoons HO_2 + O_2$	3.76e-13	1.99	603	245
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	855	2n		4.12e-13	2.30	6790	246
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	856	2n				6060	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	857	2n	$HO + C_2H_2 \leftrightharpoons HCCO + H_2$	1.91e-13	0.00	0	247
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	858	2n			0.00	1400	33
$200 2n HO + CH_3 \leftrightharpoons CH_2O + H_2 9.10e-11 0.00 1500 2$	859	2n			1.01	6010	248
	860	2n			0.00	1500	249
$661 2n HO + CHN_2 \leftrightharpoons NCO + H_2N 7.93e-13 -0.18 4770 2$	861	2n	$HO + CHN_2 \leftrightharpoons NCO + H_2N$	7.93e-13	-0.18	4770	250

Table 6—Continued

$\begin{array}{cccccccccccccccccccccccccccccccccccc$			TABLE 0—Continued				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	#	Type	Reaction	α	β	γ	Ref
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	862	2n	$HO + CHN_2 \leftrightharpoons HNC + HNO$	1.09e-17	4.44	4960	250
$\begin{array}{llllllllllllllllllllllllllllllllllll$	863						250
$\begin{array}{llllllllllllllllllllllllllllllllllll$	864	2n	$HO + CHN_2 \leftrightharpoons HCN + HNO$	6.21e-14		6750	250
$\begin{array}{llllllllllllllllllllllllllllllllllll$	865	2n		2.94e-13		1810	251
$\begin{array}{llllllllllllllllllllllllllllllllllll$	866	2n	$HO + HNCO = CO_2 + H_2N$	1.54e-14	1.50	1810	251
$\begin{array}{llllllllllllllllllllllllllllllllllll$	867	2n		2.55e-12	0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	868	2n		1.34e-13	0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	869	2n	$HO + H_3N \leftrightharpoons H_2O + H_2N$	5.25e-12	0.00	1010	252
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	870	2n		2.54e-14	3.40	0	140
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	871						
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	872					0	18
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	873				0.00	0	142
$\begin{array}{llllllllllllllllllllllllllllllllllll$	874			5.00e-11		0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	875			1.01e-11	0.00	0	253
$\begin{array}{llllllllllllllllllllllllllllllllllll$	876			4.98e-12		0	254
$\begin{array}{llllllllllllllllllllllllllllllllllll$	877		$HO + C_2H_2O \leftrightharpoons CH_2O + CHO$	4.65e-11		0	255
$\begin{array}{llllllllllllllllllllllllllllllllllll$	878			2.96e-13			256
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	879						
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	880					0	145
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	881	2n				3280	257
$\begin{array}{llllllllllllllllllllllllllllllllllll$	882	2n		9.85e-13		1040	258
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	883	2n		4.50e-13	0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	884	2n	$HO + HCOOH = CH_2O + HO_2$		0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	885	2n	$HO + HNO_3 = NO_3 + H_2O$			0	259
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	886	2n		1.37e-12		2190	260
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	887	2n		6.43e-13	2.49	2120	261
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	888	2n	$HO + C_2H_3O \leftrightharpoons C_2H_2O + H_2O$	2.01e-11	0.00	0	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	889	2n	$HO + C_2H_2O_2 \leftrightharpoons H_2O + CHO + CO$	1.10e-11	0.00	0	54
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	890			2.13e-13		0	152
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	891			1.66e-11	0.00	834	45
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	892	2n		1.10e-12		0	262
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	893	2n		6.09e-11	0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	894	2n	$HO + C_2H_5 \rightleftharpoons C_2H_4 + H_2O$	4.00e-11	0.00	0	
$\begin{array}{llllllllllllllllllllllllllllllllllll$	895				0.00	1010	59
$\begin{array}{llllllllllllllllllllllllllllllllllll$	896				0.00		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	897						263
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	898		v		0.00		
900 2n $HO + CH_3NO_3 \leftrightharpoons CH_3O + HNO_3$ 3.01e-13 0.00 0 265 901 2n $HO + C_2H_5OH \leftrightharpoons CH_3CH_2O + H_2O$ 1.60e-13 0.00 0 266	899						264
901 2n $HO + C_2H_5OH = CH_3CH_2O + H_2O$ 1.60e-13 0.00 0 266	900						265
	901						266
	902	2n	$HO + (CH_3)_2O \leftrightharpoons CH_3OCH_2 + H_2O$	5.28e-13	2.91	410	267

Table 6—Continued

		TABLE 0—Continued				
#	Type	Reaction	α	β	γ	Ref
903	2n	$HO + bCO2H5N \rightleftharpoons C_2H_4O + H_2O + NO$	8.21e-13	0.00	960	268
904	2n	$N_2 + CH_2 \leftrightharpoons HCN + HN$	8.00e-12	0.00	18000	269
905	2n	$NO + C_2O \leftrightharpoons CN + CO_2$	2.16e-11	0.00	337	270
906	2n	$NO + CH_2 \leftrightharpoons HNCO + H$	4.17e-12	0.00	3010	12
907	2n	$NO + CH_2 \leftrightharpoons HCN + HO$	8.32e-13	0.00	1440	12
908	2n	$NO + CHO \leftrightharpoons HNO + CO$	1.18e-11	0.00	0	271
909	2n	$NO + NCO \leftrightharpoons N_2O + CO$	5.15e-11	-1.34	360	272
910	2n	$NO + NCO \leftrightharpoons N_2 + CO + O$	4.21e-11	-1.98	380	3
911	2n	$NO + NCO = N_2 + CO_2$	8.05e-11	-1.98	380	3
912	2n	$NO + H_2N \leftrightharpoons N_2 + H_2O$	1.28e-10	-2.65	632	273
913	2n	$NO + H_2N \leftrightharpoons HN_2 + HO$	5.15e-09	-3.02	4830	274
914	2n	$NO + H_2N \leftrightharpoons N_2 + HO + H$	1.49e-12	0.00	0	275
915	2n	$NO + HO_2 \leftrightharpoons HNO + O_2$	1.17e-14	0.00	0	276
916	2n	$NO + N_2O \leftrightharpoons NO_2 + N_2$	2.87e-13	2.23	23300	243
917	2n	$NO + O_3 = NO_2 + O_2$	3.00e-12	0.00	1500	169
918	2n	$NO + C_2H_2 \leftrightharpoons HCN + CO + H$	8.97e-12	0.00	19000	278
919	2n	$NO + CH_3 \leftrightharpoons H_2CN + HO$	8.63e-12	0.00	12200	279
920	2n	$NO + CH_3 \leftrightharpoons HCN + H_2O$	4.00e-12	0.00	7900	279
921	2n	$NO + CH_2O = CHO + HNO$	1.69e-11	0.00	20500	18
922	2n	$NO + HNCO = HN_2 + CO_2$	8.28e-13	1.00	0	280
923	2n	$NO + H_3N \leftrightharpoons H_2N + HNO$	3.29e-13	1.73	28500	281
924	2n	$NO + NO_3 \leftrightharpoons NO_2 + NO_2$	2.60e-11	0.00	0	32
925	2n	$NO + C_2H_3 \leftrightharpoons CH_2O + HCN$	5.02e-11	-3.38	515	282
926	2n	$NO + CH_3O \Rightarrow CH_2O + HNO$	4.00e-12	-0.70	0	54
927	2n	$NO + C_2H_6 \leftrightharpoons C_2H_5 + HNO$	1.66e-10	0.00	26200	283
928	2n	$NO + (CH_3)_2O \leftrightharpoons CH_3OCH_2 + HNO$	1.66e-10	0.00	21800	284
929	2n	$NO + C_2H_5OO \Rightarrow CH_3CH_2O + NO_2$	8.70e-12	0.00	0	54
930	2n	$O_2 + C_2O = CO_2 + CO$	4.05e-13	0.00	0	285
931	2n	$O_2 + C_2O \leftrightharpoons CO + CO + O$	4.21e-13	0.00	0	286
932	2n	$O_2 + CH_2 \leftrightharpoons COOH + H$	5.74e-12	0.00	751	287
933	2n	$O_2 + CH_2 \leftrightharpoons H_2O + CO$	4.00e-13	0.00	0	7
934	2n	$O_2 + CH_2 \leftrightharpoons CO_2 + H + H$	3.74e-11	-3.30	1440	288
935	2n	$O_2 + CH_2 \leftrightharpoons CO_2 + H_2$	2.99e-11	-3.30	1440	288
936	2n	$O_2 + CH_2 \leftrightharpoons CH_2O + O$	3.74e-11	-3.30	1440	288
937	2n	$O_2 + CHO \leftrightharpoons HO_2 + CO$	6.14e-11		1560	151
938	2n	$O_2 + CHO \leftrightharpoons CO_2 + HO$	1.17e-11	0.00	1560	289
939	2n	$O_2 + NCN \leftrightharpoons CNO + NO$	2.19e-14	0.54	12300	290
940	2n	$O_2 + NCN \leftrightharpoons NCO + NO$	1.15e-13	0.51	12400	290
941	2n	$O_2 + NCO \leftrightharpoons CO_2 + NO$	1.32e-12	0.00	0	291
942	2n	$O_2 + H_2N \leftrightharpoons NH_2O + O$	8.93e-10	-1.34	17000	292
		$O_2 + H_2N \leftrightharpoons HNO + HO$	2.72e-13	-		

Table 6—Continued

$ \begin{array}{cccccccccccccccccccccccccccccccccccc$			TABLE 6—Continue	<u>a</u>			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	#	Type	Reaction	α	β	γ	Ref
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	44	2n	$O_2 + C_2H_2 \leftrightharpoons C_2H + HO_2$	2.01e-11	0.00	37500	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	45	2n	$O_2 + OCCN \leftrightharpoons CO_2 + NCO$	5.17e-13	1.64	593	293
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	46	2n	$O_2 + CH_3 \leftrightharpoons CH_2O + HO$	2.81e-13	0.00	4980	294
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	47	2n	$O_2 + CH_3 \leftrightharpoons CHO + H_2O$	1.66e-12	0.00	0	295
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	48	2n	$O_2 + CH_2O \leftrightharpoons CHO + HO_2$	9.14e-12	2.05	19100	296
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	49	2n	$O_2 + H_2O_2 \leftrightharpoons HO_2 + HO_2$	9.00e-11	0.00	20000	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	50	2n	$O_2 + C_2H_3 \leftrightharpoons CH_2CHO + O$	1.79e-11	-0.61	2650	297
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	51	2n	$O_2 + C_2H_3 \leftrightharpoons C_2H_2 + HO_2$	6.58 e-12	-1.26	1670	297
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	52	2n	$O_2 + C_2H_3 \leftrightharpoons CH_2O + CHO$	2.03e-08	-5.31	3270	297
$\begin{array}{llllllllllllllllllllllllllllllllllll$	53	2n	$O_2 + CH_4 \leftrightharpoons CH_3O_2 + H$	4.01e-12	1.96	43900	298
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	54	2n	$O_2 + CH_4 \leftrightharpoons CH_3 + HO_2$	1.26e-12	2.00	26200	299
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55	2n	$O_2 + CH_3O \leftrightharpoons CH_2O + HO_2$	3.60e-14	0.00	880	33
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	56	2n	$O_2 + CH_2OH \leftrightharpoons CH_2O + HO_2$	2.01e-12	0.00	0	145
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	57	2n	$O_2 + C_2H_4 \leftrightharpoons C_2H_3 + HO_2$	7.01e-11	0.00	29000	7
$\begin{array}{llllllllllllllllllllllllllllllllllll$	58	2n	$O_2 + C_2H_3O \leftrightharpoons C_2H_2O + HO + O$	4.20e-12	0.00	0	65
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	59	2n	$O_2 + CH_2CHO = CH_3O + CO_2$	1.10e-12	0.00	0	300
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	60	2n	$O_2 + CH_3OH \leftrightharpoons CH_2OH + HO_2$	3.40e-11	0.00	22600	145
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	61	2n	$O_2 + C_2H_5 \leftrightharpoons CH_3CH_2O + O$	6.14e-12	-0.20	14100	301
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	62	2n	$O_2 + C_2H_5 \leftrightharpoons Oxyrane + HO$	4.32e-15	0.00	0	302
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	63	2n	$O_2 + C_2H_5 \leftrightharpoons C_2H_4O + HO$	2.14e-13	-1.03	4860	301
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	64	2n	$O_2 + C_2H_5 \leftrightharpoons C_2H_4 + HO_2$	1.61e-12	-1.87	707	79
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	65	2n	$O_2 + C_2H_4O \leftrightharpoons CH_2CHO + HO_2$	3.32e-10	0.00	24400	59
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	66	2n		5.00e-11	0.00	19700	5
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	67	2n		1.00e-10	0.00	26100	5
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	68	2n		1.00e-14	0.00	4100	Est
$\begin{array}{llllllllllllllllllllllllllllllllllll$	69	2n		5.10e-12	0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	70	2n	$O_3 + CH_4 \leftrightharpoons HO_3 + CH_3$	2.66e-13	0.00	7700	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	71	2n		1.20e-14	0.00	2630	169
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	72	2n	$O_3 + C_2H_5 \leftrightharpoons CH_3CH_2O + O_2$	3.32e-14	0.00	0	303
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	73	2n	$O_3 + C_2H_4O \leftrightharpoons CH_2CHO + HO_3$	7.12e-18	3.94	14600	304
$\begin{array}{llllllllllllllllllllllllllllllllllll$	74	2n	$O_3 + C_2H_4O \leftrightharpoons C_2H_3O + HO_3$	9.37e-18	3.90	7710	304
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	75	2n	$O_3 + CH_3ONO = CH_3NO_3 + O_2$	6.76e-13	0.00	5320	305
78 2n $HN_2 + O \leftrightharpoons HNO + N$ 9.72e-19 4.84 0 79 2n $HN_2 + O \leftrightharpoons N_2 + HO$ 2.56e-11 -1.23 0 80 2n $HN_2 + CH \leftrightharpoons HCN + HN$ 3.31e-12 1.00 0	76	2n	$O_3 + C_2H_6 \leftrightharpoons C_2H_5OH + O_2$	3.94e-13	0.00	7200	306
79 2n $HN_2 + O = N_2 + HO$ 2.56e-11 -1.23 0 80 2n $HN_2 + CH = HCN + HN$ 3.31e-12 1.00 0	77	2n	$HN_2 + H \leftrightharpoons N_2 + H_2$	1.66e-12	0.00	0	25
79 2n $HN_2 + O = N_2 + HO$ 2.56e-11 -1.23 0 80 2n $HN_2 + CH = HCN + HN$ 3.31e-12 1.00 0	78	2n		9.72e-19	4.84	0	307
80 2n $HN_2 + CH = HCN + HN$ 3.31e-12 1.00 0	79						25
	80	2n				0	Est
	81						25
82 2n $HN_2 + O_2 = N_2O + HO$ 6.94e-14 -0.34 0	82						25
	83						25
	84						Est

Table 6—Continued

		TABLE 0—Continued				
#	Type	Reaction	α	β	γ	Ref
985	2n	$C_2H + C_2H \leftrightharpoons C_2H_2 + C_2$	3.01e-12	0.00	0	7
986	2n	$CH_2 + CH_2 \leftrightharpoons C_2H_2 + H + H$	2.99e-10	0.00	397	12
987	2n	$CH_2 + CH_2 \leftrightharpoons C_2H_2 + H_2$	1.80e-10	0.00	400	5
988	2n	$CHO + CHO \leftrightharpoons CO + CO + H_2$	3.64e-11	0.00	0	308
989	2n	$CHO + CHO \leftrightharpoons CH_2O + CO$	5.00e-11	0.00	0	5
990	2n	$NCO + NCO \leftrightharpoons CO + CO + N_2$	3.01e-11	0.00	0	3
991	2n	$H_2N + H_2N \leftrightharpoons NH_2NH + H$	1.00e-13	0.00	0	309
992	2n	$H_2N + H_2N \leftrightharpoons HNNH + H_2$	1.30e-12	0.00	0	309
993	2n	$HNO + HNO = H_2O + N_2O$	1.40e-15	0.00	1560	18
994	2n	$HO_2 + HO_2 \leftrightharpoons H_2 + O_2 + O_2$	1.49e-12	0.00	503	310
995	2n	$NO_2 + NO_2 \leftrightharpoons NO + NO + O_2$	2.71e-12	0.00	13100	18
996	2n	$CH_3 + CH_3 \leftrightharpoons C_2H_4 + H_2$	1.66e-10	0.00	16100	311
997	2n	$CH_3 + CH_3 \leftrightharpoons CH_4 + CH_2$	7.14e-12	0.00	5050	183
998	2n	$NO_3 + NO_3 \leftrightharpoons NO_2 + NO_2 + O_2$	8.50e-13	0.00	2450	24
999	2n	$C_2H + CH_2 \leftrightharpoons C_2H_2 + CH$	3.01e-11	0.00	0	7
1000	2n	$C_2H + HO_2 \leftrightharpoons HCCO + HO$	3.01e-11	0.00	0	7
1001	2n	$C_2H + CH_3 \leftrightharpoons C_3H_3 + H$	4.00e-11	0.00	0	7
1002	2n	$C_2H + CH_2O \leftrightharpoons C_3H_2O + H$	4.00e-11	0.00	0	312
1003	2n	$C_2H + CH_2O \leftrightharpoons C_2H_2 + CO + H$	4.00e-11	0.00	0	312
1004	2n	$C_2H + C_2H_3 \leftrightharpoons C_2H_2 + C_2H_2$	1.60e-12	0.00	0	7
1005	2n	$C_2H + CH_4 \leftrightharpoons C_2H_2 + CH_3$	1.20e-11	0.00	491	277
1006	2n	$C_2H + CH_3O \leftrightharpoons CH_2O + C_2H_2$	4.00e-11	0.00	0	7
1007	2n	$C_2H + CH_2OH \leftrightharpoons CH_2O + C_2H_2$	5.99e-11	0.00	0	145
1008	2n	$C_2H + CH_2OH = C_3H_3 + HO$	2.01e-11	0.00	0	Est
1009	2n	$C_2H + C_2H_4 \leftrightharpoons C_4H_4 + H$	1.22e-10	0.00	0	277
1010	2n	$C_2H + CH_3OH \leftrightharpoons C_2H_2 + CH_2OH$	1.00e-11	0.00	0	145
1011	2n	$C_2H + CH_3OH \leftrightharpoons C_2H_2 + CH_3O$	2.01e-12	0.00	0	145
1012	2n	$C_2H + C_2H_5 \leftrightharpoons C_2H_4 + C_2H_2$	3.01e-12	0.00	0	7
1013	2n	$C_2H + C_2H_5 \leftrightharpoons C_3H_3 + CH_3$	3.01e-11	0.00	0	7
1014	2n	$C_2H + C_2H_6 \leftrightharpoons C_2H_5 + C_2H_2$	4.72e-11	0.54	0	356
1015	2n	$C_2O + NO_2 = CO + CO + NO$	2.84e-11	0.00	0	Est
1016	2n	$C_2O + NO_2 = CO_2 + CNO$	2.84e-11	0.00	0	Est
1017	2n	$C_2O + NO_2 = CO_2 + NCO$	2.84e-11	0.00	0	Est
1018	2n	$C_2O + C_2H_4 \leftrightharpoons C_3H_4 + CO$	1.00e-14	0.00	0	Est
1019	2n	$C_2O + Oxyrane = C_2H_4 + CO + CO$	1.60e-12	0.00	0	313
1020	2n	$C_2O + Oxyrane = CH_2O + C_2H_2 + CO$	1.00e-14	0.00	0	313
1021	2n	$CH_2 + CHO \Rightarrow CH_3 + CO$	3.01e-11	0.00	0	7
1022	2n	$CH_2 + CO_2 \leftrightharpoons CH_2O + CO$	3.90e-14	0.00	0	7
1023	2n	$CH_2 + N_2O \Rightarrow HCN + NO + H$	1.00e-14	0.00	0	Est
	2n	$CH_2 + N_2O \Rightarrow CH_2O + N_2$	1.00e-14	0.00	0	Est
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Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1026	2n	$CH_2 + CH_3 \leftrightharpoons C_2H_4 + H$	1.20e-10	0.00	0	30
1027	2n	$CH_2 + CH_2O \leftrightharpoons CH_3 + CHO$	1.00e-14	0.00	0	7
1028	2n	$CH_2 + H_2O_2 \leftrightharpoons CH_3 + HO_2$	1.00e-14	0.00	0	7
1029	2n	$CH_2 + C_2H_3 \leftrightharpoons C_2H_2 + CH_3$	8.00e-11	0.00	0	30
1030	2n	$CH_2 + C_2H_2O \leftrightharpoons C_2H_4 + CO$	2.00e-10	-2.40	0	315
1031	2n	$CH_2 + CH_3O \leftrightharpoons CH_2O + CH_3$	3.01e-11	0.00	0	7
1032	2n	$CH_2 + CH_2OH \leftrightharpoons C_2H_4 + HO$	4.00e-11	0.00	0	145
1033	2n	$CH_2 + CH_2OH \leftrightharpoons CH_2O + CH_3$	2.01e-12	0.00	0	145
1034	2n	$CH_2 + C_2H_3O \leftrightharpoons C_2H_2O + CH_3$	3.01e-11	0.00	0	7
1035	2n	$CH_2 + CH_3OH \leftrightharpoons CH_2OH + CH_3$	4.38e-15	3.20	3610	145
1036	2n	$CH_2 + CH_3OH \leftrightharpoons CH_3O + CH_3$	1.12e-15	3.10	3490	145
1037	2n	$CH_2 + C_2H_5 \leftrightharpoons C_2H_4 + CH_3$	8.00e-11	0.00	0	21
1038	2n	$CH_2 + C_2H_6 \leftrightharpoons C_2H_5 + CH_3$	1.07e-11	0.00	3980	316
1039	2n	$HCN + C_2H_3 \leftrightharpoons C_3H_3N + H$	4.50e-14	0.00	0	317
1040	2n	$HNC + C_2H_3 \leftrightharpoons C_3H_3N + H$	4.50e-14	0.00	0	Est
1041	2n	$CHO + NCO \rightleftharpoons HNCO + CO$	5.99e-11	0.00	0	3
1042	2n	$CHO + H_2O \leftrightharpoons CH_2O + HO$	8.54e-13	1.53	13100	7
1043	2n	$CHO + HNO = NH_2O + CO$	8.13e-23	3.27	882	318
1044	2n	$CHO + NO_2 \leftrightharpoons CO_2 + NO + H$	1.94e-10	-0.75	971	18
1045	2n	$CHO + O_3 = CO_2 + O_2 + H$	8.30e-13	0.00	0	303
1046	2n	$CHO + CH_3 \leftrightharpoons CH_4 + CO$	2.01e-10	0.00	0	7
1047	2n	$CHO + HNCO = CH_2O + NCO$	5.00e-12	0.00	13100	3
1048	2n	$CHO + H_2O_2 = CH_2O + HO_2$	1.69e-13	0.00	3490	7
1049	2n	$CHO + HNO_2 \leftrightharpoons CH_2O + NO_2$	3.05e-15	4.18	1060	318
1050	2n	$CHO + CH_4 \leftrightharpoons CH_2O + CH_3$	1.36e-13	2.85	11300	7
1051	2n	$CHO + CH_3O \leftrightharpoons CH_3OH + CO$	1.50e-10	0.00	0	7
1052	2n	$CHO + CH_2OH \leftrightharpoons CH_3OH + CO$	2.01e-10	0.00	0	145
1053	2n	$CHO + CH_2OH \Rightarrow CH_2O + CH_2O$	3.01e-10	0.00	0	145
1054	2n	$CHO + C_2H_3O \leftrightharpoons C_2H_4O + CO$	1.50e-11	0.00	0	7
1055	2n	$CHO + CH_3OH \Rightarrow CH_2OH + CH_2O$	2.41e-13	2.90	6600	145
1056	2n	$CHO + C_2H_5 \leftrightharpoons C_2H_6 + CO$	2.01e-10	0.00	0	7
1057	2n	$CHO + C_2H_6 \leftrightharpoons C_2H_5 + CH_2O$	6.71e-15	3.74	8520	319
1058	2n	$NCO + HNO \Rightarrow HNCO + NO$	3.01e-11	0.00	0	3
1059	2n	$NCO + HO_2 \leftrightharpoons HNCO + O_2$	3.32e-11	0.00	0	142
1060	2n	$NCO + N_2O = CO + N_2 + NO$	1.50e-10		14000	3
1061	2n	$NCO + NO_2 \leftrightharpoons CO_2 + N_2O$	2.79e-11	0.00	0	3
1062	2n	$NCO + NO_2 = CO + NO + NO$	2.21e-12	0.00	0	142
1063	2n	$NCO + CH_3 = CH_2O + HNC$	7.57e-11	0.00	1840	320
1064	2n	$NCO + CH_3 = CH_2O + HCN$	1.34e-10	0.00	1840	320
1065	2n	$NCO + HCNO = HCCO + N_2O$	3.95e-12	0.00	0	Est
		-: , 11-01-0 , 11-0-0 , 11-2-0	J.000 12	0.00	~	

Table 6—Continued

		TABLE 0—Commueu				
#	Type	Reaction	α	β	γ	Ref
1067	2n	$NCO + HCNO = CO_2 + CHN_2$	3.95e-12	0.00	0	Est
1068	2n	$NCO + HCNO \Rightarrow HCN + CO + NO$	3.95e-12	0.00	0	Est
1069	2n	$NCO + HNO_2 \leftrightharpoons HNCO + NO_2$	5.99e-12	0.00	0	3
1070	2n	$NCO + C_2H_2O \leftrightharpoons HCNO + HCCO$	4.61e-12	0.00	0	Est
1071	2n	$NCO + C_2H_2O \leftrightharpoons HOCN + HCCO$	4.61e-12	0.00	0	Est
1072	2n	$NCO + C_2H_2O \leftrightharpoons HNCO + HCCO$	4.61e-12	0.00	0	Est
1073	2n	$NCO + C_2H_6 \leftrightharpoons HNCO + C_2H_5$	6.20 e-14	3.27	0	321
1074	2n	$H_2N + HO_2 \leftrightharpoons NH_2O + HO$	2.61e-10	-1.32	628	322
1075	2n	$H_2N + HO_2 \leftrightharpoons H_3N + O_2$	1.88e-16	1.55	1020	322
1076	2n	$H_2N + HO_2 \leftrightharpoons HNO + H_2O$	1.60e-11	-1.12	0	322
1077	2n	$H_2N + NO_2 \leftrightharpoons NH_2O + NO$	5.81e-12	0.00	0	323
1078	2n	$H_2N + NO_2 \leftrightharpoons N_2O + H_2O$	7.01e-12	-1.44	0	274
1079	2n	$H_2N + O_3 \leftrightharpoons NH_2O + O_2$	4.10e-12	0.00	1160	324
1080	2n	$H_2N + HNCO \leftrightharpoons H_3N + NCO$	8.30e-13	0.00	0	325
1081	2n	$H_2N + HNO_2 \leftrightharpoons H_3N + NO_2$	7.33e-10	0.00	0	326
1082	2n	$H_2N + CH_4 \leftrightharpoons CH_3 + H_3N$	6.84e-14	3.01	5000	327
1083	2n	$H_2N + H_4N_2 \leftrightharpoons NH_2NH + H_3N$	6.46 e-15	3.60	386	40
1084	2n	$H_2N + C_2H_6 \leftrightharpoons C_2H_5 + H_3N$	2.74e-14	3.46	2820	328
1085	2n	$H_2O + N_2O_3 \leftrightharpoons HNO_2 + HNO_2$	6.29 e-11	0.00	4470	329
1086	2n	$HNO + NO_2 \leftrightharpoons HNO_2 + NO$	1.00e-12	0.00	999	18
1087	2n	$HNO + O_3 \leftrightharpoons HNO_2 + O_2$	9.61e-15	3.59	0	250
1088	2n	$HNO + CH_3 \leftrightharpoons CH_3NO + H$	1.16e-14	2.40	3100	330
1089	2n	$HNO + CH_3 \leftrightharpoons CH_4 + NO$	1.85e-11	0.76	0	330
1090	2n	$HNO + CH_3O \leftrightharpoons CH_3OH + NO$	5.00e-11	0.00	0	331
1091	2n	$HO_2 + NO_2 \leftrightharpoons HNO_2 + O_2$	2.31e-13	0.58	720	332
1092	2n	$HO_2 + O_3 \leftrightharpoons HO + O_2 + O_2$	1.66e-13	0.00	1410	333
1093	2n	$HO_2 + C_2H_2 \leftrightharpoons C_2H_2O + HO$	1.00e-14	0.00	4000	7
1094	2n	$HO_2 + CH_3 \leftrightharpoons CH_3O + HO$	3.01e-11	0.00	0	5
1095	2n	$HO_2 + H_2O_2 \leftrightharpoons H_2O + HO + O_2$	1.00e-13	0.00	0	334
1096	2n	$HO_2 + NO_3 \leftrightharpoons HNO_3 + O_2$	1.91e-12	0.00	0	335
1097	2n	$HO_2 + NO_3 \leftrightharpoons NO_2 + O_2 + HO$	2.51e-12	0.00	0	335
1098	2n	$HO_2 + CH_4 \leftrightharpoons CH_3 + H_2O_2$	1.50e-11	0.00	12400	5
1099	2n	$HO_2 + CH_3O \leftrightharpoons CH_2O + H_2O_2$	5.00e-13	0.00	0	7
1100	2n	$HO_2 + CH_2OH \leftrightharpoons CH_2O + H_2O_2$	2.01e-11	0.00	0	145
1101	2n	$HO_2 + C_2H_4 \leftrightharpoons Oxyrane + HO$	3.70e-12	0.00	8650	5
1102	2n	$HO_2 + C_2H_4 \leftrightharpoons C_2H_4O + HO$	1.00e-14	0.00	4000	7
1103	2n	$HO_2 + CH_3OH \leftrightharpoons CH_2OH + H_2O_2$	1.66e-12	0.00	5050	129
1104	2n	$HO_2 + C_2H_5 \leftrightharpoons CH_3CH_2O + HO$	4.98e-11	0.00	0	301
1105	2n	$HO_2 + C_2H_5 \leftrightharpoons C_2H_4 + H_2O_2$	5.00e-13	0.00	0	7
1106	2n	$HO_2 + C_2H_4O \Rightarrow CH_2CHO + H_2O_2$	1.66e-12	0.00	7050	59
1107	2n	$HO_2 + C_2H_4O \Rightarrow C_2H_3O + H_2O_2$	5.00e-12	0.00	6000	5

Table 6—Continued

		TABLE 0—Continued				
#	Type	Reaction	α	β	γ	Ref
1108	2n	$HO_2 + C_2H_6 \leftrightharpoons C_2H_5 + H_2O_2$	6.54 e-13	2.69	9510	336
1109	2n	$HO_2 + C_2H_5OO \leftrightharpoons C_2H_6O_2 + O_2$	7.63e-12	0.00	0	266
1110	2n	$N_2O + CH_3 \leftrightharpoons CH_3O + N_2$	1.66e-09	0.00	14300	337
1111	2n	$N_2O + C_2H_4 \leftrightharpoons C_2H_4O + N_2$	1.32e-14	0.00	19100	338
1112	2n	$NO_2 + O_3 \leftrightharpoons NO_3 + O_2$	1.40e-13	0.00	2740	32
1113	2n	$NO_2 + C_2H_2 \leftrightharpoons C_2H_2O + NO$	2.09e-12	0.00	7550	Est
1114	2n	$NO_2 + CH_3 \leftrightharpoons CH_3O + NO$	2.26e-11	0.00	0	339
1115	2n	$NO_2 + CH_3 \leftrightharpoons CH_2O + HNO$	5.39e-12	0.00	0	340
1116	2n	$NO_2 + NO_3 \leftrightharpoons NO_2 + NO + O_2$	6.64e-12	0.00	2520	341
1117	2n	$NO_2 + CH_4 \leftrightharpoons HNO_2 + CH_3$	1.16e-12	0.00	15200	342
1118	2n	$NO_2 + CH_3O \leftrightharpoons CH_2O + HNO_2$	3.01e-13	0.00	0	343
1119	2n	$NO_2 + C_2H_3O \leftrightharpoons CH_3 + CO_2 + NO$	1.66e-12	0.00	0	344
1120	2n	$NO_2 + CH_3OH \leftrightharpoons CH_2OH + HNO_2$	6.09e-13	0.00	10800	345
1121	2n	$NO_2 + C_2H_5 \leftrightharpoons CH_3CH_2O + NO$	4.34e-12	-0.34	0	340
1122	2n	$NO_2 + C_2H_4O \rightleftharpoons C_2H_3O + HNO_2$	5.18e-13	0.00	13600	346
1123	2n	$NO_2 + C_2H_6 \leftrightharpoons C_2H_5 + HNO_2$	2.66e-10	0.00	17000	342
1124	2n	$NO_2 + C_2H_6N \leftrightharpoons CH_2NCH_3 + HNO_2$	6.97e-14	0.00	0	347
1125	2n	$CH_3 + C_2H_3 \leftrightharpoons C_3H_5 + H$	1.20e-10	0.00	0	348
1126	2n	$CH_3 + C_2H_3 \leftrightharpoons CH_4 + C_2H_2$	3.00e-11	0.00	0	349
1127	2n	$CH_3 + C_2H_2O \leftrightharpoons C_2H_5 + CO$	8.30e-12	0.00	0	350
1128	2n	$CH_3 + CH_4 \leftrightharpoons C_2H_6 + H$	4.95e-13	1.00	22600	351
1129	2n	$CH_3 + CH_4 \leftrightharpoons C_2H_5 + H_2$	1.66e-11	0.00	11600	352
1130	2n	$CH_3 + CH_3O \leftrightharpoons CH_2O + CH_4$	4.00e-11	0.00	0	7
1131	2n	$CH_3 + CH_2OH = CH_2O + CH_4$	4.00e-12	0.00	0	145
1132	2n	$CH_3 + C_2H_4 \leftrightharpoons C_2H_3 + CH_4$	6.91e-12	0.00	5600	5
1133	2n	$CH_3 + CH_3CN \leftrightharpoons CH_2CN + CH_4$	1.66e-14	0.00	0	353
1134	2n	$CH_3 + C_2H_3O \leftrightharpoons C_2H_6 + CO$	5.43e-11	0.00	0	354
1135	2n	$CH_3 + C_2H_3O \leftrightharpoons C_2H_2O + CH_4$	1.01e-11	0.00	0	355
1136	2n	$CH_3 + CH_3OH = CH_2OH + CH_4$	4.38e-15	3.20	3630	145
1137	2n	$CH_3 + CH_3OH = CH_3O + CH_4$	1.12e-15	3.10	3490	145
1138	2n	$CH_3 + H_4N_2 \leftrightharpoons NH_2NH + CH_4$	1.04e-14	4.00	2040	40
1139	2n	$CH_3 + C_2H_5 \leftrightharpoons C_2H_4 + CH_4$	1.50e-12	0.00	0	30
1140	2n	$CH_3 + C_2H_4O \leftrightharpoons C_2H_3O + CH_4$	2.66e-12	0.00	4030	357
1141	2n	$CH_3 + C_2H_4O \leftrightharpoons CH_2CHO + CH_4$	9.96e-12	0.00	5530	59
1142	2n	$CH_3 + C_2H_4O \leftrightharpoons (CH_3)_2CO + H$	2.76e-14		6240	Est
1143	2n	$CH_3 + Oxyrane = cyc - C_2H_3O + CH_4$	1.78e-12	0.00	5950	263
1144	2n	$CH_3 + C_2H_6 \leftrightharpoons C_2H_5 + CH_4$	2.99e-10	0.00	7510	358
1145	2n	$CH_3 + CH_3COOH = CH_3OCO + CH_4$	8.32e-13	0.00	5180	359
1146	2n	$CH_3 + C_2H_6N \leftrightharpoons CH_2NCH_3 + CH_4$	1.31e-11	0.00	0	360
1147	2n	$CH_3 + C_2H_5OH \Rightarrow CH_3OCH_2 + CH_4$	1.32e-13	0.00	4730	361
1148	2n	$CH_3 + C_2H_5OH \Rightarrow CH_3CHOH + CH_4$	6.61e-13	0.00	4880	361
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Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1149	2n	$CH_3 + (CH_3)_2O \leftrightharpoons CH_3OCH_2 + CH_4$	1.33e-11	0.00	6290	362
1150	2n	$CH_3 + (CH_3O)_2 = CH_3O + CH_2O + CH_4$	6.03e-12	0.00	5010	363
1151	2n	$H_3N + CH_3O \Rightarrow CH_3OH + H_2N$	8.32e-14	0.00	0	364
1152	2n	$H_3N + HNO_3 \leftrightharpoons H_2NNO_2 + H_2O$	5.18e-16	3.47	21700	365
1153	2n	$NO_3 + CH_4 \leftrightharpoons HNO_3 + CH_3$	8.12e-11	0.00	7060	366
1154	2n	$NO_3 + CH_3O \rightleftharpoons CH_3O_2 + NO_2$	1.79e-12	0.00	0	367
1155	2n	$NO_3 + CH_3O \leftrightharpoons CH_2O + HNO_3$	1.51e-12	0.00	0	368
1156	2n	$NO_3 + CH_3OH = CH_2OH + HNO_3$	9.40e-13	0.00	2650	369
1157	2n	$NO_3 + C_2H_5 \leftrightharpoons C_2H_4 + HNO_3$	4.00e-11	0.00	0	370
1158	2n	$NO_3 + C_2H_4O \rightleftharpoons C_2H_3O + HNO_3$	1.40e-12	0.00	1860	266
1159	2n	$NO_3 + C_2H_6 \leftrightharpoons C_2H_5 + HNO_3$	1.38e-10	0.00	4960	366
1160	2n	$NO_3 + C_2H_5OH = CH_3CHOH + HNO_3$	6.99e-13	0.00	1820	369
1161	2n	$NO_3 + (CH_3)_2O \leftrightharpoons CH_3CHOH + HNO_3$	1.40e-12	0.00	2500	371
1162	2n	$NO_3 + C_2H_5OO \rightleftharpoons CH_3CH_2O + NO_2 + O_2$	2.30e-12	0.00	0	266
1163	2n	$HOCH + HO = CO_2 + H_2 + H$	1.79e-11	0.00	0	249
1164	2n	$NH_2O + H \leftrightharpoons HNO + H_2$	1.66e-12	0.00	0	14
1165	2n	$NH_2O + HO = HNO + H_2O$	1.80e-11	0.00	0	372
1166	2n	$NH_2O + CHO = NH_2OH + CO$	1.54e-05	-2.15	0	318
1167	2n	$NH_2O + CHO = HNO + CO + H_2$	1.87e-08	-1.09	757	318
1168	2n	$NH_2O + CHO \leftrightharpoons CH_2O + HNO$	1.68e-05	-3.46	0	318
1169	2n	$NH_2O + HNO = NH_2OH + NO$	1.66e-12	0.00	1500	14
1170	2n	$NH_2O + H_2NNO_2 = NH_2OH + HNO + NO$	1.66e-12	0.00	1500	14
1171	2n	$HCCO + H = CH_2 + CO$	2.49e-10	0.00	0	41
1172	2n	HCCO + O = CO + CO + H	1.60e-10	0.00	0	5
1173	2n	$HCCO + O = CO_2 + CH$	4.90e-11	0.00	560	373
1174	2n	$HCCO + H_2 = C_2H + H_2O$	2.20e-11	0.00	2000	374
1175	2n	HCCO + NO = HCNO + CO	6.38e-11	0.00	0	374
1176	2n	$HCCO + NO = HCN + CO_2$	1.16e-11	-0.75	0	374
1177	2n	$HCCO + O_2 = CO_2 + CO + H$	2.44e-13	0.00	431	375
1178	2n	$HCCO + O_2 = CO + CO + HO$	2.71e-13	0.00	431	375
1179	2n	$HCCO + NO_2 = CHO + CO + NO$	2.58e-11	0.00	0	376
1180	2n	$HCCO + C_2H_2 = C_3H_3 + CO$	1.66e-14	0.00	0	314
1181	2n	$HNNH + H = HN_2 + H_2$	6.67e-13	2.63	0	140
1182	2n	$HNNH + HO = HN_2 + H_2O$	2.49e-13	3.40	0	140
1183	2n	$HNNH + H_2N = H_3N + HN_2$	2.27e-14		0	140
1184	2n	$COOH + CO = CO_2 + CHO$	1.00e-14	0.00	0	377
1185	2n	$COOH + O_2 \leftrightharpoons CO_2 + HO_2$	2.09e-12	0.00	0	377
1186	2n	$COOH + C_2H_2 \leftrightharpoons C_2H_3 + CO_2$	3.01e-14	0.00	0	377
1187	2n	$COOH + C_2H_4 \leftrightharpoons C_2H_5 + CO_2$	1.00e-14	0.00	0	377
1188	2n	$H_2CN + H \leftrightharpoons HCN + H_2$	2.07e-12	0.00	0	Est
	2n	$H_2CN + O = HCN + HO$	2.07e-12	0.00	0	Est

Table 6—Continued

		TABLE 0—Continuea				
#	Type	Reaction	α	β	γ	Ref
1190	2n	$H_2CN + HO \leftrightharpoons HCN + H_2O$	7.70e-12	0.00	0	378
1191	2n	$H_2CN + N_2O \leftrightharpoons CH_2N_2 + NO$	9.93e-12	0.00	22000	379
1192	2n	$HOCH + CNO \leftrightharpoons HNCO + CHO$	1.00e-11	0.00	0	3
1193	2n	$HOCH + CH_3O_2 \leftrightharpoons CH_4O_2 + CHO$	3.30e-12	0.00	5790	7
1194	2n	$C_2H_2 + C_2H_2 \leftrightharpoons C_4H_3 + H$	3.32e-12	0.00	32200	380
1195	2n	$C_2H_3 + C_2H_3 \leftrightharpoons C_4H_4 + H + H$	1.30e-11	0.00	0	381
1196	2n	$C_2H_3 + C_2H_3 \leftrightharpoons C_2H_4 + C_2H_2$	1.40e-10	0.00	0	21
1197	2n	$CH_3O + CH_3O \leftrightharpoons CH_3OH + CH_2O$	1.00e-10	0.00	0	7
1198	2n	$CH_3O + CH_2OH \leftrightharpoons CH_3OH + CH_2O$	4.00e-11	0.00	0	145
1199	2n	$C_2H_5 + C_2H_3 \leftrightharpoons C_2H_4 + C_2H_4$	8.00e-13	0.00	0	7
1200	2n	$C_2H_4 + C_2H_4 \leftrightharpoons C_4H_6 + H_2$	4.47e-08	0.00	28800	382
1201	2n	$C_2H_5 + C_2H_5 \leftrightharpoons C_2H_6 + C_2H_4$	2.41e-12	0.00	0	5
1202	2n	$C_2H_2 + NO_3 \leftrightharpoons C_2H_2O + NO_2$	4.90e-13	0.00	2770	383
1203	2n	$C_2H_2 + C_2H_3 \leftrightharpoons C_4H_4 + H$	2.62e-11	0.00	12600	384
1204	2n	$C_2H_2 + CH_3O \leftrightharpoons CH_2O + C_2H_3$	2.01e-13	0.00	10000	7
1205	2n	$C_2H_2 + CH_2OH \leftrightharpoons CH_2O + C_2H_3$	1.20e-12	0.00	4530	145
1206	2n	$C_2H_5 + C_2H_3 \leftrightharpoons C_2H_2 + C_2H_6$	8.00e-13	0.00	0	7
1207	2n	$HCCN + CH_4 \leftrightharpoons CH_3N + C_2H_2$	1.00e-13	0.00	0	386
1208	2n	$HCCN + C_2H_4 \leftrightharpoons C_2H_3N + C_2H_2$	1.00e-13	0.00	0	386
1209	2n	$CH_2O + C_2H_3 \leftrightharpoons C_2H_4 + CHO$	8.07e-14	2.81	2950	7
1210	2n	$CH_2O + CH_3O \leftrightharpoons CH_3OH + CHO$	1.69e-13	0.00	1500	7
1211	2n	$CH_2O + C_2H_3O \leftrightharpoons C_2H_4O + CHO$	3.01e-13	0.00	6500	7
1212	2n	$HNCO + NO_3 \leftrightharpoons HNO + CO_2 + NO$	1.66e-12	0.00	5030	142
1213	2n	$H_2O_2 + C_2H_3 \leftrightharpoons C_2H_4 + HO_2$	5.45e-14	0.00	0	7
1214	2n	$HNO_2 + NO_3 \leftrightharpoons HNO_3 + NO_2$	2.01e-15	0.00	0	387
1215	2n	$C_2H_3 + CH_3O \leftrightharpoons CH_2O + C_2H_4$	4.00e-11	0.00	0	7
1216	2n	$C_2H_3 + CH_2OH \leftrightharpoons CH_2O + C_2H_4$	5.00e-11	0.00	0	145
1217	2n	$C_2H_3 + CH_2OH \leftrightharpoons C_3H_5 + HO$	2.01e-11	0.00	0	145
1218	2n	$C_2H_3 + C_2H_4 \leftrightharpoons C_4H_6 + H$	8.30e-13	0.00	3860	388
1219	2n	$C_2H_3 + C_2H_3O \leftrightharpoons C_3H_3O + CH_3$	3.01e-11	0.00	0	7
1220	2n	$C_2H_3 + CH_3OH = CH_2OH + C_2H_4$	4.38e-15	3.20	3630	145
1221	2n	$C_2H_3 + CH_3OH \leftrightharpoons CH_3O + C_2H_4$	1.12e-15	3.10	3490	145
1222	2n	$C_2H_3 + C_2H_4O \leftrightharpoons C_2H_3O + C_2H_4$	1.35e-13	0.00	1850	389
1223	2n	$C_2H_3 + C_2H_6 \leftrightharpoons C_2H_5 + C_2H_4$	1.46e-13	3.30	5280	7
1224	2n	$CH_3O + C_2H_3O \leftrightharpoons C_2H_2O + CH_3OH$	1.00e-11	0.00	0	7
1225	2n	$CH_3O + C_2H_3O \leftrightharpoons CH_2O + C_2H_4O$	1.00e-11	0.00	0	7
1226	2n	$CH_3O + C_2H_5 \leftrightharpoons CH_2O + C_2H_6$	4.00e-11	0.00	0	7
1227	2n	$CH_3O + C_2H_4O \leftrightharpoons CH_3OH + C_2H_3O$	8.30e-15	0.00	0	390
1228	2n	$CH_3O + C_2H_6 \leftrightharpoons CH_3OH + C_2H_5$	4.00e-13	0.00	3570	7
1229	2n	$CH_3O + CH_3COOH \Rightarrow CH_3OH + CH_3OCO$	1.69e-11	0.00	4120	391
1230	2n	$C_2H_4 + C_2H_5OO = Oxyrane + CH_3CH_2O$	3.79e-08	0.00	11000	392
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Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1231	2n	$H_4N_2 + C_2H_5 \leftrightharpoons C_2H_6 + NH_2NH$	8.32e-14	0.00	2300	393
1232	2n	$C_2H_5 + C_2H_4O \leftrightharpoons C_2H_6 + C_2H_3O$	2.09e-12	0.00	4280	394
1233	2n	$C_2H_5 + C_2H_5NO \leftrightharpoons C_4H_{10} + NO$	1.66e-10	0.00	0	395
1234	2n	$C_2H_6 + C_2H_5OO \leftrightharpoons (CH_3O)_2 + C_2H_5$	2.87e-14	3.76	8650	396
1235	2n	$H_2CN + H_2CN \leftrightharpoons CH_3N + HCN$	7.70e-12	0.00	0	397
1236	2n	$CH_3O_2 + H \leftrightharpoons CH_3O + HO$	1.60e-10	0.00	0	7
1237	2n	$CH_3O_2 + O \leftrightharpoons CH_3O + O_2$	8.30e-11	0.00	0	398
1238	2n	$CH_3O_2 + H_2 \leftrightharpoons CH_4O_2 + H$	5.00e-11	0.00	13100	7
1239	2n	$CH_3O_2 + HO \leftrightharpoons CH_3OH + O_2$	1.00e-10	0.00	0	7
1240	2n	$CH_3O_2 + NO \leftrightharpoons CH_3O + NO_2$	7.51e-12	0.00	0	399
1241	2n	$CH_3O_2 + O_2 \leftrightharpoons HCOOH + HO_2$	3.50e-14	0.00	0	400
1242	2n	$CH_3O_2 + C_2H \leftrightharpoons CH_3O + HCCO$	4.00e-11	0.00	0	7
1243	2n	$CH_3O_2 + CH_2 \leftrightharpoons CH_3O + CH_2O$	3.01e-11	0.00	0	7
1244	2n	$CH_3O_2 + HO_2 \leftrightharpoons CH_4O_2 + O_2$	1.57e-11	0.00	0	7
1245	2n	$CH_3O_2 + CH_3 \leftrightharpoons CH_3O + CH_3O$	4.00e-11	0.00	0	7
1246	2n	$CH_3O_2 + CH_2O \leftrightharpoons CH_4O_2 + CHO$	3.30e-12	0.00	5870	7
1247	2n	$CH_3O_2 + H_2O_2 \leftrightharpoons CH_4O_2 + HO_2$	4.00e-12	0.00	5000	7
1248	2n	$CH_3O_2 + NO_3 \leftrightharpoons CH_3O + NO_2 + O_2$	3.11e-12	0.00	0	368
1249	2n	$CH_3O_2 + C_2H_3 \leftrightharpoons cyc-C_2H_3O + CH_3O$	4.00e-11	0.00	0	7
1250	2n	$CH_3O_2 + CH_4 \leftrightharpoons CH_4O_2 + CH_3$	3.01e-13	0.00	9300	7
1251	2n	$CH_3O_2 + CH_3O \leftrightharpoons CH_4O_2 + CH_2O$	5.00e-13	0.00	0	7
1252	2n	$CH_3O_2 + CH_2OH \leftrightharpoons CH_4O_2 + CH_2O$	2.01e-11	0.00	0	Est
1253	2n	$CH_3O_2 + CH_3OH \leftrightharpoons CH_4O_2 + CH_2OH$	3.01e-12	0.00	6900	145
1254	2n	$CH_3O_2 + C_2H_5 \leftrightharpoons CH_3CH_2O + CH_3O$	4.00e-11	0.00	0	7
1255	2n	$CH_3O_2 + C_2H_6 \leftrightharpoons CH_4O_2 + C_2H_5$	4.90e-13	0.00	7520	7
1256	2n	$C_2H_2O + C_2H_2O \leftrightharpoons C_3H_4 + CO_2$	1.83e-11	0.00	18000	401
1257	2n	$CH_2OH + CH_2OH \leftrightharpoons CH_3OH + CH_2O$	8.00e-12	0.00	0	145
1258	2n	$C_2H_3O + C_2H_3O \leftrightharpoons C_2H_2O + C_2H_4O$	1.49e-11	0.00	0	355
1259	2n	$CH_2OH + C_2H_5 \leftrightharpoons CH_2O + C_2H_6$	4.00e-12	0.00	0	145
1260	2n	$CH_2OH + C_2H_5 \leftrightharpoons CH_3OH + C_2H_4$	4.00e-12	0.00	0	145
1261	2n	$CH_2OH + C_2H_6 \leftrightharpoons CH_3OH + C_2H_5$	8.73 e-15	3.00	7030	145
1262	2n	$C_2H_3O + CH_3OH \leftrightharpoons C_2H_4O + CH_2OH$	2.13e-13	3.00	6210	145
1263	2n	$C_2H_3O + C_2H_4O \leftrightharpoons (CH_3)_2CO + CHO$	2.84e-13	0.00	0	402
1264	2n	$C_2H_3O + C_2H_6N \leftrightharpoons C_2H_4O + CH_2NCH_3$	5.98e-11	0.00	0	360
1265	2n	$CH_3NO + CH_3O \leftrightharpoons C_2H_5NO_2 + H$	1.00e-10	0.50	2340	403
1266	2n	$NH_2OH + HO \leftrightharpoons H_2O + NH_2O$	4.13e-11	0.00	2140	257
1267	2n	$CH_3O_2 + CH_3O_2 \leftrightharpoons CH_3O + CH_3O + O_2$	7.40e-13	0.00	519	266
1268	2n	$CH_3O_2 + CH_3O_2 \leftrightharpoons (CH_3O)_2 + O_2$	3.01e-14	0.00	0	Est
1269	2n	$CH_3O_2 + CH_3O_2 \leftrightharpoons CH_3OH + CH_2O + O_2$	2.22e-13	0.00	0	Est
1270	2n	$CH_3OCO + CH_3O \leftrightharpoons CH_3COOH + CH_2O$	3.79e-11	0.00	0	404
		$C_2H_6O_2 + O \leftrightharpoons CH_3CH_2O + HO_2$	8.80e-12			5

Table 6—Continued

# Type Reaction α β γ 1272 2n $C_2H_6O_2 + O = CH_3CHOH + HO_2$ 8.80e-12 0.57 139 2n $CH_2CHO + CH_3OH = C_2H_4O + CH_2OH$ 2.13e-13 3.00 621 1274 2n $CH_2CHO + C_2H_4O = (CH_3)_2CO + CHO$ 2.84e-13 0.00 0 1275 2n $CH_2CHO + C_2H_6 = C_2H_4O + C_2H_5$ 1.91e-13 2.75 882 1276 2n $CH_2CHO + C_2H_6 = C_2H_4O + C_2H_5$ 1.91e-13 2.75 882 1276 2n $CH_2CHO + C_2H_6N = C_2H_4O + C_2H_5$ 1.91e-13 2.75 882 1276 2n $CH_2CHO + C_2H_6N = C_2H_4O + C_2H_5$ 3.01e-12 0.00 0 0 1277 2n $(CH_3)_2N_2O + HO = C_2H_6 + HO_2 + N_2$ 3.01e-12 0.00 0 0 1277 2n $(CH_3)_2N_2O + HO = C_2H_6 + HO_2 + N_2$ 3.01e-12 0.00 0 0 1278 2n $CH_3OCH_2 + H = C_2H_4O + H_2$ 3.32e-11 0.00 0 0 1280 2n $CH_3OCH_2 + O = CH_3COOH + H$ 3.03e-09 0.00 0 0 1280 2n $CH_3OCH_2 + O = CH_3O + CH_2O$ 1.50e-10 0.00 0 0 1281 2n $CH_3OCH_2 + O = C_2H_4O + HO$ 3.16e-10 0.00 0 0 1282 2n $CH_3OCH_2 + O = C_2H_4O + HO$ 3.16e-10 0.00 0 0 1283 2n $CH_3OCH_2 + O = C_2H_4O + HNO$ 1.30e-11 0.00 0 0 1283 2n $CH_3OCH_2 + O = C_2H_4O + CH_2O + CH_2O$ 1.11e-13 0.00 38 1284 2n $CH_3OCH_2 + O = C_2H_4O + CH_2O + HO$ 8.30e-12 0.00 106 1285 2n $CH_3OCH_2 + O = C_2H_4O + CH_2O + HO$ 8.30e-12 0.00 106 1285 2n $CH_3OCH_2 + NO = C_2H_4O + HNO_2$ 6.61e-12 0.00 0 1286 2n $CH_3OCH_2 + NO_3 = C_2H_3O + CH_2O + HO$ 8.30e-12 0.00 106 1286 2n $CH_3OCH_2 + NO_3 = C_2H_3O + C_2H_4$ 1.14e-07 1.00 0 1287 2n $CH_3OCH_2 + C_2H_5 = C_2H_4O + C_2H_6$ 6.46e-08 1.00 0 1288 2n $CH_3OCH_2 + C_2H_5 = C_2H_4O + C_2H_6$ 6.46e-08 1.00 0 0 1290 2n $CH_3CHOH + H = C_2H_4O + HO$ 3.32e-11 0.00 0 0 1291 2n $CH_3CHOH + NO = C_2H_4O + HO$ 3.32e-11 0.00 0 0 1292 2n $CH_3CHOH + NO = C_2H_4O + HO$ 3.32e-11 0.00 0 0 1292 2n $CH_3CHOH + NO = C_2H_4O + HO$ 3.30e-12 0.00 0 0 1299 2n $CH_3CHOH + NO = C_2H_4O + HO$ 3.30e-12 0.00 0 0 1299 2n $CH_3CHOH + NO = C_2H_4O + HO$ 3.30e-12 0.00 0 0 1299 2n $CH_3CHOH + NO = C_2H_4O + HO$ 3.30e-12 0.00 0 0 1299 2n $CH_3CHOH + NO = C_2H_4O + HO$ 3.30e-12 0.00 0 0 1299 2n $CH_3CHOH + NO = C_2H_4O + HO$ 4.40e-11 0.00 55 1299 2n $CH_3CH_2O + NO_3 = C_2H_4O + HNO$ 3.30e-12 0.00 0 0 1299 2n	
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1301 2n $O(^{1}D) + O_{2} = O + O_{2}$ 4.00e-11 0.00 0	415
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1302 2n $O(^{1}D) + O_{3} = O_{2} + O_{2}$ 1.20e-10 0.00 0	169
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1303 2n $O(^{1}D) + O_{3} = O_{2} + O + O$ 1.20e-10 0.00 0	169
1304 2n $O(^{1}D) + H_{2} = HO + H$ 1.20e-10 0.00 0	169
1305 2n $O(^{1}D) + H_{2}O = HO + HO$ 2.00e-10 0.00 0	169
1306 2n $O(^{1}D) + N_{2} = O + N_{2}$ 3.10e-11 0.00 0	169
1307 2n $O(^{1}D) + N_{2}O = N_{2} + O_{2}$ 4.95e-11 0.00 0	169
1308 2n $O(^{1}D) + N_{2}O = NO + NO$ 7.25e-11 0.00 0	169
1309 2n $O(^{1}D) + H_{3}N = H_{2}N + HO$ 2.50e-10 0.00 0	169
1310 2n $O(^{1}D) + CO_{2} = O + CO_{2}$ 1.10e-10 0.00 0	169
1311 2n $O(^{1}D) + CH_{4} = CH_{3} + HO$ 1.31e-10 0.00 0	169
1312 2n $O(^{1}D) + CH_{4} = CH_{3}O + H$ 3.50e-11 0.00 0	169

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
1313	2n	$O(^{1}D) + CH_{4} \leftrightharpoons CH_{2}O + H_{2}$	9.00e-12	0.00	0	169
1314	2n	$O(^{1}D) + CH_{4} \leftrightharpoons CH_{2}O + H_{2}$	9.00e-12	0.00	0	169
1315	2n	$O(^{1}S) + O_{2} \leftrightharpoons O + O_{2}$	2.85e-13	0.00	0	169
1316	2n	$O(^{1}S) + O_{3} \leftrightharpoons O_{2} + O_{2}$	2.30e-10	0.00	0	169
1317	2n	$O(^{1}S) + O_{3} \leftrightharpoons O_{2} + O + O$	2.30e-10	0.00	0	169
1318	2n	$O(^{1}S) + H_{2}O \leftrightharpoons HO + HO$	6.38e-10	0.00	0	169
1319	2n	$O(^{1}S) + CO_{2} \leftrightharpoons O + CO_{2}$	3.09e-13	0.00	0	169
1320	2n	$O(^{1}S) + H_{2} \leftrightharpoons HO + H$	3.60e-10	0.00	0	169
1321	2n	$O(^{1}S) + N_{2} \leftrightharpoons O + N_{2}$	3.09e-13	0.00	0	169
1322	2n	$C(^{1}D) + H_{2} \leftrightharpoons CH + H$	9.50e-11	0.00	0	169
1323	2n	$C(^{1}S) + H_{2} \leftrightharpoons CH + H$	2.10e-10	0.00	0	169
1324	2n	$O_2(a^1 \Delta_g) + O_3 = O_2 + O_2 + O$	5.20e-11	0.00	2840	169
1325	2n	$O_2(a^1\Delta_g) + H_2O \leftrightharpoons O_2 + H_2O$	1.00e-11	0.00	0	169
1326	2n	$CH_2^* + H \leftrightharpoons CH + H_2$	3.00e-10	0.00	0	21
1327	2n	$CH_2^* + H_2 \leftrightharpoons CH_3 + H$	1.26e-11	0.00	0	21
1328	2n	$CH_2^* + H_2 \leftrightharpoons CH_2 + H_2$	9.24e-11	0.00	0	21
1329	2n	$CH_2^* + O_2 \leftrightharpoons HO + CO + H$	4.60e-11	0.00	0	21
1330	2n	$CH_2^* + O_2 = H_2O + CO$	2.00e-11	0.00	0	21
1331	2n	$CH_3 + HO = CH_2^* + H_2O$	1.61e-13	2.57	2010	21
1332	2n	$CH_2^* + H_2O = CH_2 + H_2O$	5.00e-11	0.00	0	21
1333	2n	$CH_2^* + H_2O \leftrightharpoons CH_2 + H_2O$	5.00e-11	0.00	0	21
1334	2n	$CH_2^* + CO \leftrightharpoons CH_2 + CO$	5.00e-11	0.00	0	21
1335 1336	2n 2n	$CH_2^* + N_2 \leftrightharpoons HN + HCN$ $CH_2^* + NO \leftrightharpoons HCNO + H$	1.66e-13 6.43e-12	0.00 -0.40	$32700 \\ 292$	21 21
1337	2n	$CH_2 + NO = HCNO + HC$		-0.40	382	21
1338	2n	$CH_2 + NO \rightarrow HCN + HO$ $CH_2^* + CH_3 \Leftrightarrow C_2H_4 + H$	8.86e-12 7.00e-11	0.00	0	$\frac{21}{385}$
1339	2n	$CH_2 + CH_3 \rightarrow C_2H_4 + H$ $CH_2 + C_3H_3 \leftrightharpoons C_4H_4 + H$	3.00e-11	0.00	0	21
1340	2n	$C_1 + C_3 + C_3 + C_4 + C_4 + C_4 + C_4 + C_4 + C_5 + C_6 $	5.05e-11	0.00	297	685
1341	2n	$C_2H + C_2H_2 \rightleftharpoons C_4H_2 + H$	1.30e-10	0.00	0	686
1342	2n	$C_4H + H_2 \leftrightharpoons C_4H_2 + H$	2.18e-12	2.17	478	385
1343	2n	$C_4H + CH_4 \rightleftharpoons C_4H_2 + CH_3$	1.20e-11	0.00	491	385
1344	2n	$C_4H + C_2H_6 \leftrightharpoons C_4H_2 + C_2H_5$	4.72e-11	0.54	0	385
1345	2n	$NaH + H \leftrightharpoons Na + H_2$	2.38e-12	0.69	2360	160
1346	2n	$Na + H_2O \rightleftharpoons NaOH + H$	4.07e-10	0.00	21900	417
1347	2n	$KH + H = K + H_2$	2.38e-12	0.69	2360	100
1348	2n	$K + H_2O = KOH + H$	5.00e-10	0.00	20000	417
1349	2n	$H + HCl \leftrightharpoons H_2 + Cl$	6.84e-19	0.00	1730	418
1350	2n	$HCl + HO = H_2O + Cl$	5.89e-18	2.12	0	419
1351	2n	K + HCl = KCl + H	5.60 e-10	0.00	4170	420
1352	2n	$Na + HCl \leftrightharpoons NaCl + H$	4.00e-10	0.00	4090	421
1353	2i	$Ar^+ + CH_4 \leftrightharpoons CH_2^+ + H_2 + Ar$	9.00e-10	0.00	0	422

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1354	2i	$Ar^+ + CH_4 \leftrightharpoons CH_3^+ + H + Ar$	9.00e-10	0.00	0	422
1355	2i	$Ar^+ + CH_4 \leftrightharpoons CH_4^+ + Ar$	9.00e-10	0.00	0	422
1356	2i	$Ar^+ + CO = CO^+ + Ar$	5.00e-11	0.00	0	423
1357	2i	$Ar^+ + CO_2 \leftrightharpoons CO_2^+ + Ar$	5.00e-10	0.00	0	424
1358	2i	$Ar^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + H + Ar$	5.00e-10	0.00	0	425
1359	2i	$Ar^+ + C_2H_6 \leftrightharpoons C_2H_4^+ + H_2 + Ar$	5.00e-10	0.00	0	425
1360	2i	$Ar^+ + C_2H_6 \leftrightharpoons C_2H_3^+ + H_2 + H + Ar$	5.00e-10	0.00	0	425
1361	2i	$Ar^{+} + C_{2}H_{6} \leftrightharpoons C_{2}H_{2}^{+} + H_{2} + H_{2} + Ar$	5.00e-10	0.00	0	425
1362	2i	$Ar^+ + H_2 \leftrightharpoons ArH^+ + H$	2.20e-09	0.00	2320	426
1363	2i	$Ar^+ + H_2 \leftrightharpoons H_2^+ + Ar$	1.00e-09	0.00	0	426
1364	2i	$Ar^+ + H_2O = ArH^+ + HO$	1.30e-09	0.00	0	427
1365	2i	$Ar^+ + H_2O \leftrightharpoons H_2O^+ + Ar$	1.50e-10	0.00	0	427
1366	2i	$Ar^+ + H_3N \leftrightharpoons H_3N^+ + Ar$	1.69e-09	0.00	0	428
1367	2i	$Ar^+ + H_3N \leftrightharpoons H_2N^+ + H + Ar$	5.52e-11	0.00	0	428
1368	2i	$Ar^+ + H_3N \leftrightharpoons ArH^+ + H_2N$	9.20e-11	0.00	0	428
1369	2i	$Ar^+ + NO \leftrightharpoons NO^+ + Ar$	4.00e-10	0.00	464	429
1370	2i	$Ar^+ + NO_2 \leftrightharpoons NO_2^+ + Ar$	1.30e-10	0.00	464	430
1371	2i	$Ar^+ + NO_2 \leftrightharpoons NO^+ + O + Ar$	1.30e-10	0.00	464	430
1372	2i	$Ar^+ + N_2 \leftrightharpoons N_2^+ + Ar$	6.50 e-10	0.00	1740	431
1373	2i	$Ar^+ + N_2O \leftrightharpoons N_2O^+ + Ar$	3.10e-10	0.00	1740	426
1374	2i	$Ar^+ + O_2 = O_2^+ + Ar$	6.00e-11	0.00	464	429
1375	2i	$ArH^+ + CH_4 \leftrightharpoons CH_5^+ + Ar$	1.00e-9	0.00	580	432
1376	2i	$ArH^+ + CO \leftrightharpoons CHO^+ + Ar$	1.25e-9	0.00	580	432
1377	2i	$ArH^+ + CO_2 \leftrightharpoons CHO_2^+ + Ar$	1.10e-9	0.00	580	432
1378	2i	$ArH^+ + H_2 \leftrightharpoons H_3^+ + Ar$	1.50e-9	0.00	0	433
1379	2i	$ArH^+ + H_2O \leftrightharpoons H_3O^+ + Ar$	4.50e-09	0.00	0	434
1380	2i	$ArH^+ + N_2 \leftrightharpoons HN_2^+ + Ar$	8.00e-10	0.00	580	432
1381	2i	$ArH^+ + O_2 \leftrightharpoons HO_2^+ + Ar$	4.10e-10	0.00	0	435
1382	2i	$ArH_3^+ + CO \leftrightharpoons CHO^+ + H_2 + Ar$	1.20e-09	0.00	0	436
1383	2i	$ArH_3^+ + CO_2 \leftrightharpoons CHO_2^+ + H_2 + Ar$	1.20e-09	0.00	0	436
1384	2i	$ArH_3^+ + C_2H_4 \leftrightharpoons C_2H_3^+ + H_2 + H_2 + Ar$	1.75e-09	0.00	0	436
1385	2i	$ArH_3^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + H_2 + Ar$	7.50e-10	0.00	0	436
1386	2i	$ArH_3^+ + NO \leftrightharpoons HNO^+ + H_2 + Ar$	1.60e-09	0.00	0	436
1387	2i	$ArH_3^+ + N_2 \leftrightharpoons HN_2^+ + H_2 + Ar$	8.50e-10	0.00	0	436
1388	2i	$ArH_3^+ + N_2O \leftrightharpoons HN_2O^+ + H_2 + Ar$	1.80e-09	0.00	0	436
1389	2i	$Ar_2^+ + CO = CO^+ + Ar + Ar$	8.50e-10	0.00	0	437
1390	2i	$Ar_2^+ + CO_2 \leftrightharpoons CO_2^+ + Ar + Ar$	1.10e-09	0.00	0	437
1391	2i	$Ar_2^+ + H_2 \leftrightharpoons Ar_2H^+ + H$	4.90e-10	0.00	0	438
1392	2i	$Ar_2^+ + H_2 \leftrightharpoons ArH^+ + H + Ar$	4.70e-10	0.00	0	439
1393	2i	$Ar_2^+ + H_3N \leftrightharpoons H_3N^+ + Ar + Ar$	4.50 e-10	0.00	0	430
1394	2i	$Ar_2^+ + NO \leftrightharpoons NO^+ + Ar + Ar$	2.40e-11	0.00	0	437

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1395	2i	$Ar_2^+ + NO_2 \leftrightharpoons NO_2^+ + Ar + Ar$	2.80e-10	0.00	0	430
1396	2i	$Ar_2^+ + NO_2 \leftrightharpoons NO^+ + O + Ar + Ar$	2.80e-10	0.00	0	430
1397	2i	$Ar_2^+ + N_2O \leftrightharpoons N_2O^+ + Ar + Ar$	8.20e-10	0.00	0	430
1398	2i	$Ar_2^+ + O_2 \leftrightharpoons O_2^+ + Ar + Ar$	7.40e-11	0.00	0	430
1399	2i	$Ar_2H^+ + H_2 \leftrightharpoons ArH_3^+ + Ar$	1.20e-10	0.00	0	440
1400	2i	$C^+ + HCN \leftrightharpoons C_2N^+ + H$	1.30e-09	0.00	0	441
1401	2i	$C^+ + CH_2O \leftrightharpoons CH_2^+ + CO$	2.34e-09	0.00	0	442
1402	2i	$C^+ + CH_2O \leftrightharpoons CHO^+ + CH$	7.80e-10	0.00	0	442
1403	2i	$C^+ + CH_2O \leftrightharpoons CH_2O^+ + C$	7.80e-10	0.00	0	442
1404	2i	$C^+ + HCOOH = CHO^+ + CHO$	3.30e-09	0.00	0	443
1405	2i	$C^+ + CH_4 \leftrightharpoons C_2H_3^+ + H$	1.03e-09	0.00	0	442
1406	2i	$C^+ + CH_4 \leftrightharpoons C_2H_2^+ + H_2$	4.21e-10	0.00	0	442
1407	2i	$C^+ + CH_3OH \leftrightharpoons CH_4O^+ + C$	1.35e-09	0.00	0	442
1408	2i	$C^+ + CH_3OH \leftrightharpoons CH_3O^+ + CH$	1.23e-09	0.00	0	442
1409	2i	$C^+ + CH_3OH = CH_3^+ + CHO$	1.19e-09	0.00	0	442
1410	2i	$C^+ + CH_3OH \leftrightharpoons CHO^+ + CH_3$	3.28e-10	0.00	0	442
1411	2i	$C^+ + CH_5N \leftrightharpoons CH_5N^+ + C$	3.07e-09	0.00	0	442
1412	2i	$C^+ + CH_5N \leftrightharpoons CH_4N^+ + CH$	7.98e-10	0.00	0	442
1413	2i	$C^+ + CH_5N \leftrightharpoons CH_2N^+ + CH_3$	2.52e-10	0.00	0	442
1414	2i	$C^+ + CH_5N \leftrightharpoons CH_3^+ + HCN + H$	1.26e-10	0.00	0	442
1415	2i	$C^+ + CO_2 \leftrightharpoons CO^+ + CO$	1.60e-09	0.00	0	444
1416	2i	$C^+ + C_2H_2 \leftrightharpoons C_3H^+ + H$	2.20e-09	0.00	0	445
1417	2i	$C^+ + C_2H_4 \leftrightharpoons C_3H_2^+ + H_2$	5.20 e-10	0.00	0	445
1418	2i	$C^+ + C_2H_4 \leftrightharpoons C_3H_3^+ + H$	3.90e-10	0.00	0	445
1419	2i	$C^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + C$	1.95e-10	0.00	0	445
1420	2i	$C^+ + C_2H_4 \leftrightharpoons C_2H_3^+ + CH$	1.95e-10	0.00	0	445
1421	2i	$C^+ + C_2H_6 \leftrightharpoons C_3H_3^+ + H_2 + H$	4.80e-10	0.00	0	445
1422	2i	$C^+ + C_2H_6 \leftrightharpoons C_2H_3^+ + CH_3$	4.80e-10	0.00	0	445
1423	2i	$C^+ + C_2H_6 \leftrightharpoons C_2H_4^+ + CH_2$	3.20e-10	0.00	0	445
1424	2i	$C^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + CH$	3.20e-10	0.00	0	445
1425	2i	$C^+ + NCCN \leftrightharpoons C_2N^+ + CN$	1.90e-09	0.00	0	446
1426	2i	$C^+ + H_2 \leftrightharpoons CH^+ + H$	2.20e-12	0.00	4480	Est
1427	2i	$C^+ + H_2O \leftrightharpoons CHO^+ + H$	2.70e-09	0.00	0	442
1428	2i	$C^+ + H_3N \leftrightharpoons H_3N^+ + C$	1.15e-09	0.00	0	442
1429	2i	$C^+ + H_3N \leftrightharpoons CH_2N^+ + H$	1.08e-09	0.00	0	442
1430	2i	$C^+ + H_3N \leftrightharpoons CHN^+ + H_2$	6.90e-11	0.00	0	442
1431	2i	$C^+ + SiH_4 \leftrightharpoons Si^+ + H_2 + H_2 + C$	4.36e-09	0.00	0	447
1432	2i	$C^+ + SiH_4 \leftrightharpoons SiH^+ + H_2 + H + C$	4.36e-09	0.00	0	447
1433	2i	$C^+ + SiH_4 \leftrightharpoons SiH_2^+ + H_2 + C$	4.36e-09	0.00	0	447
1434	2i	$C^+ + SiH_4 \leftrightharpoons SiH_3^+ + H + C$	4.36e-09	0.00	0	447
1435	2i	$C^+ + SiH_4 \leftrightharpoons SiH_4^+ + C$	4.36e-09	0.00	0	447

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1436	2i	$C^+ + SiH_4 \leftrightharpoons SiCH^+ + H_2 + H$	4.36e-09	0.00	0	447
1437	2i	$C^+ + SiH_4 \leftrightharpoons SiCH_2^+ + H_2$	4.36e-09	0.00	0	447
1438	2i	$C^+ + NO = NO^+ + C$	8.50 e-10	0.00	0	442
1439	2i	$C^+ + N_2O \leftrightharpoons NO^+ + CN$	9.10e-10	0.00	0	448
1440	2i	$C^+ + O_2 \leftrightharpoons CO^+ + O$	7.81e-10	0.00	0	442
1441	2i	$C^+ + O_2 \leftrightharpoons O^+ + CO$	4.39e-10	0.00	0	442
1442	2i	$CH^+ + HCN \leftrightharpoons C_2N^+ + H_2$	4.29e-10	0.00	0	441
1443	2i	$CH^+ + HCN \leftrightharpoons C_2HN^+ + H$	2.31e-10	0.00	0	441
1444	2i	$CH^+ + HCN \leftrightharpoons CH_2N^+ + C$	2.80e-09	0.00	0	441
1445	2i	$CH^+ + CH_2O \leftrightharpoons CHO^+ + CH_2$	9.60e-10	0.00	0	449
1446	2i	$CH^+ + CH_2O \leftrightharpoons CH_3^+ + CO$	9.60e-10	0.00	0	449
1447	2i	$CH^+ + CH_2O \rightleftharpoons CH_3O^+ + C$	9.60e-10	0.00	0	449
1448	2i	$CH^+ + CH_2O \rightleftharpoons C_2H_2O^+ + H$	3.20e-10	0.00	0	449
1449	2i	$CH^+ + CH_4 \leftrightharpoons C_2H_3^+ + H_2$	1.09e-09	0.00	0	107
1450	2i	$CH^{+} + CH_{4} \leftrightharpoons C_{2}H_{2}^{+} + H_{2} + H$	1.43e-10	0.00	0	107
1451	2i	$CH^+ + CH_4 \leftrightharpoons C_2H_4^+ + H$	6.50 e-11	0.00	0	107
1452	2i	$CH^+ + CH_3OH \leftrightharpoons CH_3^+ + CH_2O$	1.45e-09	0.00	0	449
1453	2i	$CH^+ + CH_3OH \rightleftharpoons CH_5O^+ + C$	1.16e-09	0.00	0	449
1454	2i	$CH^+ + CH_3OH \leftrightharpoons CH_3O^+ + CH_2$	2.90e-10	0.00	0	449
1455	2i	$CH^+ + CH_5N \leftrightharpoons CH_4N^+ + CH_2$	1.10e-09	0.00	0	449
1456	2i	$CH^+ + CH_5N \leftrightharpoons CH_6N^+ + C$	8.80e-10	0.00	0	449
1457	2i	$CH^+ + CH_5N \leftrightharpoons CH_5N^+ + CH$	2.20e-10	0.00	0	449
1458	2i	$CH^+ + CO \leftrightharpoons CHO^+ + C$	7.00e-12	0.00	0	450
1459	2i	$CH^+ + CO_2 \leftrightharpoons CHO^+ + CO$	1.60e-09	0.00	0	450
1460	2i	$CH^+ + C_2H_2 \leftrightharpoons C_3H_2^+ + H$	2.40e-09	0.00	0	451
1461	2i	$CH^+ + H_2 \leftrightharpoons CH_2^+ + H$	1.20e-09	0.00	0	450
1462	2i	$CH^+ + H_2O \leftrightharpoons CHO^+ + H_2$	1.35e-09	0.00	0	450
1463	2i	$CH^+ + H_2O \leftrightharpoons CH_2O^+ + H$	6.75e-10	0.00	0	450
1464	2i	$CH^+ + H_2O \leftrightharpoons H_3O^+ + C$	6.75e-10	0.00	0	450
1465	2i	$CH^{+} + H_{3}N \leftrightharpoons CH_{2}N^{+} + H_{2}$	1.84e-09	0.00	0	452
1466	2i	$CH^+ + H_3N \leftrightharpoons H_3N^+ + CH$	4.59e-10	0.00	0	452
1467	2i	$CH^+ + H_3N \leftrightharpoons H_4N^+ + C$	4.05e-10	0.00	0	452
1468	2i	$CH^{+} + SiH_{4} \leftrightharpoons Si^{+} + H_{2} + H_{2} + CH$	4.56e-09	0.00	0	447
1469	2i	$CH^+ + SiH_4 \leftrightharpoons SiH^+ + H_2 + CH + H$	4.56e-09	0.00	0	447
1470	2i	$CH^+ + SiH_4 \leftrightharpoons SiH_2^+ + H_2 + CH$	4.56e-09	0.00	0	447
1471	2i	$CH^+ + SiH_4 \leftrightharpoons SiH_3^+ + CH + H$	4.56e-09	0.00	0	447
1472	2i	$CH^+ + SiH_4 \leftrightharpoons SiCH_2^+ + H_2 + H$	4.56e-09	0.00	0	447
1473	2i	$CH^+ + SiH_4 \leftrightharpoons SiCH_3^+ + H_2$	4.56e-09	0.00	0	447
1474	2i	$CH^+ + N \leftrightharpoons CN^+ + H$	1.90e-10	0.00	0	453
1475	2i	$CH^+ + N \leftrightharpoons H^+ + CN$	1.90e-10	0.00	0	453
1476	2i	$CH^+ + NO \leftrightharpoons NO^+ + CH$	7.60e-10	0.00	0	453

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1477	2i	$CH^+ + O \leftrightharpoons CO^+ + H$	3.50e-10	0.00	0	453
1478	2i	$CH^+ + O = H^+ + CO$	3.50e-10	0.00	0	453
1479	2i	$CH^+ + O_2 \leftrightharpoons CHO^+ + O$	4.85e-10	0.00	0	450
1480	2i	$CH^+ + O_2 \leftrightharpoons CO^+ + HO$	2.43e-10	0.00	0	450
1481	2i	$CH^+ + O_2 \leftrightharpoons O^+ + CHO$	2.43e-10	0.00	0	450
1482	2i	$CHN^+ + HCN \leftrightharpoons CH_2N^+ + CN$	1.20e-09	0.00	0	441
1483	2i	$CHN^{+} + HCN \leftrightharpoons C_{2}HN_{2}^{+} + H$	3.20e-11	0.00	0	441
1484	2i	$CHN^{+} + CH_{4} \leftrightharpoons CH_{2}N^{+} + CH_{3}$	1.09e-09	0.00	0	454
1485	2i	$CHN^{+} + CH_{4} \leftrightharpoons C_{2}H_{3}^{+} + H_{2}N$	2.08e-10	0.00	0	454
1486	2i	$CHN^{+} + CH_{5}N \leftrightharpoons CH_{6}N^{+} + CN$	1.50e-09	0.00	0	455
1487	2i	$CHN^{+} + CO \leftrightharpoons CHO^{+} + CN$	1.40e-10	0.00	0	456
1488	2i	$CHN^{+} + CO_{2} \leftrightharpoons CHO_{2}^{+} + CN$	2.10e-10	0.00	0	456
1489	2i	$CHN^+ + H_2 \leftrightharpoons CH_2N^+ + H$	9.81e-10	0.00	0	457
1490	2i	$CHN^{+} + H_{2}O \rightleftharpoons H_{3}O^{+} + CN$	1.80e-09	0.00	0	456
1491	2i	$CHN^{+} + H_{2}O \rightleftharpoons H_{2}O^{+} + HCN$	1.80e-09	0.00	0	456
1492	2i	$CHN^{+} + H_{2}O \leftrightharpoons CH_{2}N^{+} + HO$	1.44e-10	0.00	0	456
1493	2i	$CHN^{+} + H_{3}N \leftrightharpoons H_{3}N^{+} + HCN$	1.89e-09	0.00	0	456
1494	2i	$CHN^{+} + H_{3}N \leftrightharpoons CH_{2}N^{+} + H_{2}N$	8.40e-10	0.00	0	456
1495	2i	$CHN^{+} + H_{3}N \leftrightharpoons H_{4}N^{+} + CN$	1.40e-10	0.00	0	456
1496	2i	$CHN^{+} + O_{2} \leftrightharpoons O_{2}^{+} + HCN$	3.20e-10	0.00	0	456
1497	2i	$CHNO^{+} + HNCO = CH_{2}NO^{+} + CNO$	8.30e-10	0.00	0	458
1498	2i	$CHO^+ + Ar \leftrightharpoons ArH^+ + CO$	3.90e-10	0.00	0	459
1499	2i	$CHO^+ + HCN \rightleftharpoons CH_2N^+ + CO$	4.00e-09	0.00	0	457
1500	2i	$CHO^+ + HNCO = CH_2NO^+ + CO$	1.34e-09	0.00	0	458
1501	2i	$CHO^+ + CH_2O \rightleftharpoons CH_3O^+ + CO$	6.10e-10	0.00	0	460
1502	2i	$CHO^{+} + HCOOH = CH_{3}O_{2}^{+} + CO$	1.80e-09	0.00	0	461
1503	2i	$CHO^+ + CH_3NO_2 \leftrightharpoons CH_4NO_2^+ + CO$	3.33e-09	0.00	0	462
1504	2i	$CHO^{+} + CH_{3}NO_{2} = NO^{+} + CH_{3}OH + CO$	3.33e-09	0.00	0	462
1505	2i	$CHO^{+} + CH_{3}OH = CH_{5}O^{+} + CO$	2.40e-09	0.00	0	463
1506	2i	$CHO^+ + CO_2 \leftrightharpoons CHO_2^+ + CO$	1.25e-09	0.00	0	459
1507	2i	$CHO^{+} + C_{2}H_{2} = C_{2}H_{3}^{+} + CO$	1.36e-09	0.00	0	464
1508	2i	$CHO^{+} + C_{2}H_{2}O = C_{2}H_{3}O^{+} + CO$	1.80e-09	0.00	0	461
1509	2i	$CHO^{+} + CH_{3}CN = C_{2}H_{4}N^{+} + CO$	4.10e-09	0.00	0	465
1510	2i	$CHO^{+} + C_{2}H_{4}O = C_{2}H_{5}O^{+} + CO$	3.69e-09	0.00	0	466
1511	2i	$CHO^{+} + CH_{3}COOH = C_{2}H_{5}O_{2}^{+} + CO$	2.50e-09	0.00	0	461
1512	2i	$CHO^{+} + C_{2}H_{6} = C_{2}H_{7}^{+} + CO$	1.20e-10	0.00	0	467
1513	2i	$CHO^{+} + C_{2}H_{5}OH = C_{2}H_{7}O^{+} + CO$	2.20e-09	0.00	0	461
1514	2i	$CHO^{+} + (CH_3)_2O = C_2H_7O^{+} + CO$	2.10e-09	0.00	0	468
1515	2i	$CHO^{+} + HC_{3}N = C_{3}H_{2}N^{+} + CO$	4.00e-09	0.00	0	469
1516	2i	$CHO^+ + H_2O \rightleftharpoons H_3O^+ + CO$	2.50e-09	0.00	0	463
1517	2i	$CHO^+ + H_3N \leftrightharpoons H_4N^+ + CO$	1.12e-09	0.00	0	470

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1518	2i	$CHO^+ + N_2O \leftrightharpoons HN_2O^+ + CO$	2.70e-12	0.00	0	435
1519	2i	$CHO^+ + O_2 \leftrightharpoons HO_2^+ + CO$	4.80e-10	0.00	0	459
1520	2i	$CHO_2^+ + CH_3NO_2 = CH_4NO_2^+ + CO_2$	2.81e-09	0.00	0	462
1521	2i	$CHO_2^+ + CH_3NO_2 \leftrightharpoons NO^+ + CH_3OH + CO_2$	8.46e-12	0.00	0	462
1522	2i	$CHO_2^+ + CH_4 \leftrightharpoons CH_5^+ + CO_2$	1.30e-10	0.00	0	471
1523	2i	$CHO_2^+ + C_2H_2 \leftrightharpoons C_2H_3^+ + CO_2$	1.37e-09	0.00	0	464
1524	2i	$CHO_2^+ + CH_3CN \leftrightharpoons C_2H_4N^+ + CO_2$	4.10e-09	0.00	0	465
1525	2i	$CHO_2^+ + H_2O \leftrightharpoons H_3O^+ + CO_2$	3.00e-09	0.00	0	472
1526	2i	$CH_2^+ + HCN \leftrightharpoons C_2H_2N^+ + H$	1.80e-09	0.00	0	473
1527	2i	$CH_2^+ + CH_2O \leftrightharpoons CH_3^+ + CHO$	6.40 e-10	0.00	0	460
1528	2i	$CH_2^+ + CH_2O \leftrightharpoons CHO^+ + CH_3$	2.80e-09	0.00	0	449
1529	2i	$CH_2^+ + CH_2O \leftrightharpoons C_2H_3O^+ + H$	3.30e-10	0.00	0	449
1530	2i	$CH_2^+ + CH_2O \leftrightharpoons C_2H_2O^+ + H_2$	1.65e-10	0.00	0	449
1531	2i	$CH_2^+ + CH_4 \leftrightharpoons C_2H_4^+ + H_2$	8.40e-10	0.00	0	107
1532	2i	$CH_2^+ + CH_4 \leftrightharpoons C_2H_5^+ + H$	3.60e-10	0.00	0	107
1533	2i	$CH_2^+ + CH_3OH \leftrightharpoons CH_3O^+ + CH_3$	1.30e-09	0.00	0	449
1534	2i	$CH_2^+ + CH_3OH \leftrightharpoons CH_5O^+ + CH$	1.30e-09	0.00	0	449
1535	2i	$CH_2^+ + CH_5N \leftrightharpoons CH_4N^+ + CH_3$	1.16e-09	0.00	0	449
1536	2i	$CH_2^+ + CH_5N \leftrightharpoons CH_5N^+ + CH_2$	7.35e-10	0.00	0	449
1537	2i	$CH_2^+ + CH_5N \leftrightharpoons CH_6N^+ + CH$	2.10e-10	0.00	0	449
1538	2i	$CH_2^+ + CO = CHO^+ + CH$	4.99e-12	-2.50	0	104
1539	2i	$CH_2^+ + CO_2 \leftrightharpoons CH_2O^+ + CO$	1.60e-09	0.00	0	450
1540	2i	$CH_2^+ + C_2H_2 \leftrightharpoons C_3H_3^+ + H$	2.50e-09	0.00	0	473
1541	2i	$CH_2^+ + C_2H_2O = C_2H_2O^+ + CH_2$	3.80e-10	0.00	0	474
1542	2i	$CH_2^+ + H_2 = CH_3^+ + H$	1.60e-09	0.00	0	450
1543	2i	$CH_2^+ + H_2O \rightleftharpoons CH_3O^+ + H$	2.90e-09	0.00	0	450
1544	2i	$CH_2^+ + H_2O = H_3O^+ + CH$	2.90e-09	0.00	0	450
1545	2i	$CH_2^+ + H_3N \leftrightharpoons CH_4N^+ + H$	1.54e-09	0.00	0	452
1546	2i	$CH_2^+ + H_3N \leftrightharpoons H_4N^+ + CH$	1.26e-09	0.00	0	452
1547	2i	$CH_2^+ + SiH_4 \leftrightharpoons SiH^+ + CH + H_2 + H_2$	3.49e-09	0.00	0	447
1548	2i	$CH_2^{+} + SiH_4 = SiH_2^{+} + CH + H_2 + H$	3.49e-09	0.00	0	447
1549	2i	$CH_2^{\overline{1}} + SiH_4 = SiH_3^{\overline{1}} + CH + H_2$	3.49e-09	0.00	0	447
1550	2i	$CH_2^+ + SiH_4 \leftrightharpoons SiCH_2^+ + H_2 + H_2$	3.49e-09	0.00	0	447
1551	2i 2i	$CH_2^+ + SiH_4 \leftrightharpoons SiCH_3^+ + H_2 + H$ $CH_2^+ + N \leftrightharpoons CN^+ + H_2$	3.49e-09 2.20e-10	0.00	0	447 453
1552 1553	21 2i	$CH_2 + N = CN^+ + H_2$ $CH_2^+ + N = CHN^+ + H$	2.20e-10 2.20e-10	$0.00 \\ 0.00$		453 453
		$CH_2 + N = CHN^+ + H$ $CH_2^+ + NO = NO^+ + CH_2$			0	
1554 1555	2i 2i	$CH_2^+ + NO = NO^+ + CH_2$ $CH_2^+ + O_2 = CHO^+ + HO$	4.20e-10 9.10e-10	$0.00 \\ 0.00$	0	$453 \\ 450$
1556	21 2i	$CH_2^+ + O_2 = CHO^+ + HO$ $CH_2^+ + O_2 = CH_2O^+ + O$	9.10e-10 9.10e-10	0.00	0	$450 \\ 450$
1550 1557	2i	$CH_2 + O_2 = CH_2O^+ + O$ $CH_2N^+ + CH_2O = CH_3O^+ + HCN$	9.10e-10 2.10e-09	0.00	0	475
1557 1558	2i	$CH_2N^+ + CH_2O \Rightarrow CH_3O^+ + HCN$ $CH_2N^+ + CH_3NO_2 \Rightarrow CH_4NO_2^+ + HCN$	3.75e-09	0.00		462
1999	$\angle 1$	O_{112} IN + O_{113} IN $O_2 \Rightarrow O_{14}$ IN $O_2 + IIO$ IN	5.75e-09	0.00	0	402

Table 6—Continued

$\begin{array}{cccccccccccccccccccccccccccccccccccc$			Table 6—Continued				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	#	Type	Reaction	α	β	γ	Ref
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1559	2i	$CH_2N^+ + CH_5N \leftrightharpoons CH_6N^+ + HNC$	5.00e-10	0.00	0	455
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1560	2i	$CH_2N^+ + H_3N \leftrightharpoons H_4N^+ + HCN$	2.40e-09	0.00	0	457
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1561	2i	$CH_2O^+ + CH_2O \leftrightharpoons CH_3O^+ + CHO$	1.65e-09	0.00	0	460
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1562	2i	$CH_2O^+ + CH_2O \leftrightharpoons CH_4O^+ + CO$	1.24e-10	0.00	0	460
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1563	2i		9.35e-11	0.00	0	463
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1564	2i	$CH_2O^+ + CH_4 \leftrightharpoons C_2H_5O^+ + H$	1.65e-11	0.00	0	463
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1565	2i		2.16e-09	0.00	0	463
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1566					0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1567			2.60e-09		0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1568			1.28e-09		0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1569					0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1570					0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1571			3.30e-11	0.00	0	463
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1572			1.60e-09	0.00	0	449
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1573	2i		1.50e-09	0.00	0	476
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1574	2i		1.00e-09	0.00	0	476
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1575	2i	$CH_3^+ + CH_3OH \leftrightharpoons CH_3O^+ + CH_4$	2.30e-09	0.00	0	449
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1576	2i	$CH_3^+ + CH_5N \leftrightharpoons CH_5N^+ + CH_3$	1.21e-09	0.00	0	477
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1577	2i	$CH_3^+ + CH_5N \leftrightharpoons CH_4N^+ + CH_4$	9.90e-10	0.00	0	477
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1578	2i	$CH_3^+ + C_2H_2 \leftrightharpoons C_3H_3^+ + H_2$	1.20e-09	0.00	0	477
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1579	2i	$CH_3^+ + C_2H_4O \leftrightharpoons C_2H_3O^+ + CH_4$	2.10e-10	0.00	0	478
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1580	2i	$CH_3^+ + C_2H_4O \leftrightharpoons CH_3O^+ + C_2H_4$	5.61e-10	0.00	0	478
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1581	2i	$CH_3^+ + C_2H_4O \leftrightharpoons C_2H_3^+ + CH_3OH$	3.08e-10	0.00	0	478
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1582	2i	$CH_3^+ + C_2H_4O \leftrightharpoons C_2H_4^+ + CH_3O$	1.98e-10	0.00	0	478
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1583	2i	$CH_3^+ + C_2H_4O \leftrightharpoons C_3H_5O^+ + H_2$	3.30e-11	0.00	0	478
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1584	2i	$CH_3^+ + C_2H_4O \leftrightharpoons C_3H_5O^+ + H_2$	3.30e-11	0.00	0	478
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1585	2i	$CH_3^+ + C_2H_4O \leftrightharpoons C_3H_6O^+ + H$	1.68e-11	0.00	0	478
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1586	2i	$CH_3^+ + (CH_3)_2O \leftrightharpoons C_2H_5O^+ + CH_4$	1.98e-09	0.00	0	Est
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1587	2i	$CH_3^+ + HC_3N \leftrightharpoons C_3H_3^+ + HCN$	2.52e-09	0.00	0	479
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1588	2i	$CH_3^+ + H_2 \leftrightharpoons CH_4^+ + H$	5.00e-13	0.00	0	480
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1589	2i	$CH_3^+ + H_2O \leftrightharpoons CH_2OH^+ + H_2$	9.99e-12	0.00	0	481
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1590	2i	$CH_3^+ + H_3N \leftrightharpoons CH_4N^+ + H_2$	2.00e-09	0.00	0	482
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1591	2i	$CH_3^+ + H_3N \leftrightharpoons H_4N^+ + CH_2$	1.66e-10	0.00	0	482
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1592	2i	$CH_3^+ + SiH_4 \leftrightharpoons SiH_3^+ + CH_4$	2.39e-09	0.00	0	447
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1593	2i		2.39e-09	0.00	0	447
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1594					0	
1596 2i $CH_3^+ + NO \leftrightharpoons NO^+ + CH_3$ 1.00e-09 0.00 0 453 1597 2i $CH_3^+ + O \leftrightharpoons CHO^+ + H_2$ 3.08e-10 0.00 0 483 1598 2i $CH_3^+ + O \leftrightharpoons H_3^+ + CO$ 8.80e-11 0.00 0 483	1595						
1597 2i $CH_3^+ + O = CHO^+ + H_2$ 3.08e-10 0.00 0 483 1598 2i $CH_3^+ + O = H_3^+ + CO$ 8.80e-11 0.00 0 483	1596						
1598 2i $CH_3^+ + O = H_3^+ + CO$ 8.80e-11 0.00 0 483	1597						
	1598						
	1599	2i	$CH_3^+ + O \leftrightharpoons CH_2O^+ + H$	4.40e-11	0.00	0	483

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1600	2i	$CH_3O^+ + HCN \leftrightharpoons CH_2N^+ + CH_2O$	1.30e-09	0.00	0	475
1601	2i	$CH_3O^+ + CH_2O \leftrightharpoons C_2H_2O^+ + H_2O + H$	1.81e-12	0.00	0	460
1602	2i	$CH_3O^+ + CH_2O \leftrightharpoons C_2H_3O^+ + H_2O$	1.81e-12	0.00	0	460
1603	2i	$CH_3O^+ + CH_2O \leftrightharpoons C_2H_5O^+ + O$	1.81e-12	0.00	0	460
1604	2i	$CH_3O^+ + CH_2O \leftrightharpoons CH_5O^+ + CO$	1.21e-12	0.00	0	460
1605	2i	$CH_3O^+ + H_2O \leftrightharpoons H_3O^+ + CH_2O$	3.00e-11	0.00	0	463
1606	2i	$CH_3O^+ + H_3N \leftrightharpoons H_4N^+ + CH_2O$	8.57e-10	0.00	0	470
1607	2i	$CH_4^+ + HCN \leftrightharpoons CH_2N^+ + CH_3$	3.23e-09	0.00	0	473
1608	2i	$CH_4^+ + HCN \leftrightharpoons C_2H_4N^+ + H$	6.60e-11	0.00	0	473
1609	2i	$CH_4^+ + CH_2O \leftrightharpoons CH_3O^+ + CH_3$	1.98e-09	0.00	0	449
1610	2i	$CH_4^+ + CH_2O \leftrightharpoons CH_2O^+ + CH_4$	1.62e-09	0.00	0	449
1611	2i	$CH_4^+ + CH_4 \leftrightharpoons CH_5^+ + CH_3$	1.20e-09	0.00	0	484
1612	2i	$CH_4^+ + CH_3OH \leftrightharpoons CH_4O^+ + CH_4$	1.80e-09	0.00	0	449
1613	2i	$CH_4^+ + CH_3OH \leftrightharpoons CH_5O^+ + CH_3$	1.20e-09	0.00	0	449
1614	2i	$CH_4^+ + CH_5N \leftrightharpoons CH_5N^+ + CH_4$	1.32e-09	0.00	0	449
1615	2i	$CH_4^+ + CH_5N \leftrightharpoons CH_4N^+ + CH_4 + H$	8.80e-10	0.00	0	449
1616	2i	$CH_4^+ + CO \leftrightharpoons CHO^+ + CH_3$	1.40e-09	0.00	0	485
1617	2i	$CH_4^+ + CO \leftrightharpoons C_2H_3O^+ + H$	6.08e-10	0.00	0	485
1618	2i	$CH_4^+ + CO_2 \leftrightharpoons CHO_2^+ + CH_3$	1.20e-09	0.00	0	485
1619	2i	$CH_4^+ + CO_2 \leftrightharpoons C_2H_3O^+ + HO$	9.60e-12	0.00	0	485
1620	2i	$CH_4^+ + C_2H_2 \leftrightharpoons C_2H_3^+ + CH_3$	1.25 e-09	0.00	0	473
1621	2i	$CH_4^+ + C_2H_2 \leftrightharpoons C_2H_2^+ + CH_4$	1.13e-09	0.00	0	473
1622	2i	$CH_4^{+} + C_2H_2 \leftrightharpoons C_3H_3^{+} + H_2 + H$	1.25e-10	0.00	0	473
1623	2i	$CH_4^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + CH_3$	2.90e-09	0.00	0	486
1624	2i	$CH_4^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + CH_4$	2.90e-09	0.00	0	486
1625	2i	$CH_4^+ + C_2H_4 \leftrightharpoons C_3H_6^+ + H_2$	2.90e-09	0.00	0	486
1626	2i	$CH_4^+ + C_2H_4 \leftrightharpoons C_3H_7^+ + H$	2.90e-09	0.00	0	486
1627	2i	$CH_4^+ + H_2 \leftrightharpoons CH_5^+ + H$	3.30e-11	0.00	0	450
1628	2i	$CH_4^+ + H_2O \leftrightharpoons H_3O^+ + CH_3$	3.33e-09	0.00	0	427
1629	2i	$CH_4^+ + H_2O \leftrightharpoons CH_5O^+ + H$	1.75e-10	0.00	0	427
1630	2i	$CH_4^+ + H_3N \leftrightharpoons H_3N^+ + CH_4$	1.65e-09	0.00	0	485
1631	2i	$CH_4^+ + H_3N \leftrightharpoons H_4N^+ + CH_3$	1.15e-09	0.00	0	485
1632	2i	$CH_4^+ + H_3N \leftrightharpoons CH_5^+ + H_2N$	6.32e-11	0.00	0	485
1633	2i	$CH_4^+ + SiH_4 \leftrightharpoons SiH_2^+ + CH_4 + H_2$	2.04e-09	0.00	0	447
1634	2i	$CH_4^{\uparrow} + SiH_4 \leftrightharpoons SiH_3^{\uparrow} + CH_4 + H$	2.04e-09	0.00	0	447
1635	2i	$CH_4^+ + SiH_4 \leftrightharpoons SiCH_4^+ + H_2 + H_2$	2.04e-09	0.00	0	447
1636	2i	$CH_4^+ + SiH_4 \leftrightharpoons SiCH_5^+ + H_2 + H$	2.04e-09	0.00	0	447
1637	2i	$CH_4^+ + NO = NO^+ + CH_4$	2.80e-10	0.00	0	487
1638	2i	$CH_4^+ + N_2O \leftrightharpoons HN_2O^+ + CH_3$	1.01e-09	0.00	0	488
1639	2i	$CH_4^+ + N_2O \leftrightharpoons HNO^+ + CH_3N$	3.12e-11	0.00	0	488
1640	2i	$CH_4^+ + O_2 \leftrightharpoons O_2^+ + CH_4$	4.40e-10	0.00	0	450

Table 6—Continued

		TABLE 0—Continued				
#	Type	Reaction	α	β	γ	Ref
1641	2i	$CH_4N^+ + CH_5N \leftrightharpoons CH_6N^+ + CH_3N$	4.00e-10	0.00	0	455
1642	2i	$CH_4N^+ + CH_5N \leftrightharpoons CH_6N^+ + CH_3N$	4.00e-10	0.00	0	455
1643	2i	$CH_4NO_2^+ + HC_3N \leftrightharpoons C_3H_2N^+ + CH_3NO_2$	9.00e-10	0.00	0	469
1644	2i	$CH_4O^+ + CH_3OH \leftrightharpoons CH_5O^+ + CH_3O$	2.50e-09	0.00	0	489
1645	2i	$CH_4O^+ + H_3N \leftrightharpoons H_4N^+ + CH_3O$	3.40e-09	0.00	0	470
1646	2i	$CH_5^+ + CH_2O \leftrightharpoons CH_3O^+ + CH_4$	4.50e-09	0.00	0	490
1647	2i	$CH_5^+ + HCOOH \leftrightharpoons CH_3O_2^+ + CH_4$	2.90e-09	0.00	0	491
1648	2i	$CH_5^+ + CH_3NO_2 \leftrightharpoons CH_4NO_2^+ + CH_4$	4.13e-09	0.00	0	462
1649	2i	$CH_5^+ + CH_3NO_2 \leftrightharpoons NO^+ + CH_3OH + CH_4$	2.89e-12	0.00	0	462
1650	2i	$CH_5^+ + CO \leftrightharpoons CHO^+ + CH_4$	9.90e-10	0.00	0	492
1651	2i	$CH_5^+ + CO_2 \leftrightharpoons CHO_2^+ + CH_4$	3.30e-11	0.00	0	493
1652	2i	$CH_5^+ + C_2H_2 \leftrightharpoons C_2H_3^+ + CH_4$	1.56e-09	0.00	0	464
1653	2i	$CH_5^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + CH_4$	1.00e-09	0.00	0	494
1654	2i	$CH_5^+ + CH_3OCHO = C_2H_5O_2^+ + CH_4$	4.10e-09	0.00	0	495
1655	2i	$CH_5^+ + C_2H_6 \leftrightharpoons C_2H_7^+ + CH_4^-$	1.28e-09	0.00	0	467
1656	2i	$CH_5^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + CH_4 + H_2$	2.25e-10	0.00	0	467
1657	2i	$CH_5^+ + H_2O \leftrightharpoons H_3O^+ + CH_4$	3.70e-09	0.00	0	472
1658	2i	$CH_5^+ + H_3N \leftrightharpoons H_4N^+ + CH_4$	2.30e-09	0.00	0	496
1659	2i	$CH_5^+ + SiH_4 \leftrightharpoons SiH_3^+ + CH_4 + H_2$	1.99e-09	0.00	0	447
1660	2i	$CH_5^+ + NO = HNO^+ + CH_4$	9.99e-12	0.00	0	433
1661	2i	$CH_5^+ + N_2O \rightleftharpoons HN_2O^+ + CH_4$	9.50e-10	0.00	0	497
1662	2i	$CH_5^+ + O \rightleftharpoons H_3O^+ + CH_2$	2.16e-10	0.00	0	453
1663	2i	$CH_5^+ + O = CH_3O^+ + H_2$	4.40e-12	0.00	0	453
1664	2i	$CH_5O^+ + HCN = C_2H_4N^+ + H_2O$	2.30e-11	0.00	0	498
1665	2i	$CH_5O^+ + CH_2O \leftrightharpoons C_2H_5O^+ + H_2O$	2.10e-11	0.00	0	499
1666	2i	$CH_5O^+ + CH_3NO_2 \leftrightharpoons CH_4NO_2^+ + CH_3OH$	1.32e-09	0.00	0	462
1667	2i	$CH_5O^+ + CH_3OH = C_2H_7O^+ + H_2O$	1.08e-10	0.00	0	499
1668	2i	$CN^+ + HCN = CHN^+ + CN$	1.79e-09	0.00	0	500
1669	2i	$CN^+ + HCN \leftrightharpoons C_2N_2^+ + H$	3.15e-10	0.00	0	500
1670	2i	$CN^+ + HCOOH = \tilde{C}HO^+ + HCNO$	5.30e-09	0.00	0	443
1671	2i	$CN^+ + CH_4 \leftrightharpoons CH_3^+ + HCN$	4.50e-10	0.00	0	500
1672	2i	$CN^+ + CH_4 = CH_4^+ + CN$	1.35e-10	0.00	0	500
1673	2i	$CN^+ + CH_4 \leftrightharpoons CHN^+ + CH_3$	1.35e-10	0.00	0	500
1674	2i	$CN^+ + CH_4 \leftrightharpoons CH_2N^+ + CH_2$	9.00e-11	0.00	0	500
1675	2i	$CN^+ + CH_4 \leftrightharpoons C_2H_2N^+ + H_2$	9.00e-11	0.00	0	500
1676	2i	$CN^+ + CH_3OH = CH_3O^+ + HCN$	1.56e-09	0.00	0	500
1677	2i	$CN^+ + CH_3OH = CH_4O^+ + CN$	7.80e-10	0.00	0	500
1678	2i	$CN^+ + CH_3OH = CH_2N^+ + CH_2O$	2.60e-10	0.00	0	500
1679	2i	$CN^+ + CO = CO^+ + CN$	6.30e-10	0.00	0	501
1680	2i	$CN^+ + CO_2 = CO_2^+ + CN$	3.00e-10	0.00	0	500
1000	21	$Civ + CO_2 \rightarrow CO_3 + Civ$	0.000 10			000

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1682	2i	$CN^+ + CO_2 \leftrightharpoons C_2O^+ + NO$	2.25e-10	0.00	0	500
1683	2i	$CN^+ + C_2H_4 = C_2H_4^+ + CN$	8.80e-10	0.00	0	501
1684	2i	$CN^+ + C_2H_4 \leftrightharpoons CHN^+ + C_2H_3$	4.00e-10	0.00	0	501
1685	2i	$CN^+ + C_2H_4 \leftrightharpoons C_2H_3^+ + HCN$	1.60e-10	0.00	0	501
1686	2i	$CN^+ + C_2H_4 \leftrightharpoons CH_2N^+ + C_2H_2$	1.60e-10	0.00	0	501
1687	2i	$CN^+ + C_2H_6 \leftrightharpoons C_2H_4^+ + HCN + H$	1.24e-09	0.00	0	501
1688	2i	$CN^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + HCN$	3.80e-10	0.00	0	501
1689	2i	$CN^+ + C_2H_6 \leftrightharpoons C_2H_3^+ + HCN + H_2$	2.85e-10	0.00	0	501
1690	2i	$CN^+ + NCCN \leftrightharpoons C_2N_2^+ + CN$	1.19e-09	0.00	0	500
1691	2i	$CN^+ + NCCN \leftrightharpoons C_3N^+ + N_2$	1.40e-10	0.00	0	500
1692	2i	$CN^+ + NCCN \leftrightharpoons C_2N^+ + CN_2$	7.00e-11	0.00	0	500
1693	2i	$CN^+ + HC_3N \leftrightharpoons C_3HN^+ + CN$	3.12e-09	0.00	0	479
1694	2i	$CN^+ + HC_3N \leftrightharpoons C_3N^+ + HCN$	7.80e-10	0.00	0	479
1695	2i	$CN^+ + H_2 \leftrightharpoons CHN^+ + H$	1.00e-09	0.00	0	500
1696	2i	$CN^+ + H_2O \leftrightharpoons CHN^+ + HO$	1.60e-09	0.00	0	501
1697	2i	$CN^+ + H_2O \leftrightharpoons CHNO^+ + H$	6.40 e-10	0.00	0	501
1698	2i	$CN^+ + H_2O \leftrightharpoons CH_2N^+ + O$	4.80e-10	0.00	0	501
1699	2i	$CN^+ + H_2O \rightleftharpoons H_2O^+ + CN$	3.20e-10	0.00	0	501
1700	2i	$CN^+ + H_2O \rightleftharpoons CHO^+ + HN$	1.60e-10	0.00	0	501
1701	2i	$CN^+ + H_3N \leftrightharpoons H_3N^+ + CN$	1.20e-09	0.00	0	501
1702	2i	$CN^+ + H_3N \leftrightharpoons CHN^+ + H_2N$	4.00e-10	0.00	0	501
1703	2i	$CN^+ + H_3N \leftrightharpoons CH_2N^+ + HN$	3.00e-10	0.00	0	501
1704	2i	$CN^+ + H_3N \leftrightharpoons H_2N^+ + HCN$	1.00e-10	0.00	0	501
1705	2i	$CN^+ + NO \rightleftharpoons NO^+ + CN$	5.70e-10	0.00	0	500
1706	2i	$CN^+ + NO \leftrightharpoons CNO^+ + N$	1.90e-10	0.00	0	500
1707	2i	$CN^+ + N_2O \rightleftharpoons N_2O^+ + CN$	4.56e-10	0.00	0	500
1708	2i	$CN^+ + N_2O \leftrightharpoons CNO^+ + N_2$	1.52e-10	0.00	0	500
1709	2i	$CN^+ + N_2O \rightleftharpoons NO^+ + CN_2$	1.52e-10	0.00	0	500
1710	2i	$CN^+ + O_2 \leftrightharpoons O_2^+ + CN$	2.58e-10	0.00	0	500
1711	2i	$CN^+ + O_2 \leftrightharpoons CNO^+ + O$	8.60e-11	0.00	0	500
1712	2i	$CN^+ + O_2 \leftrightharpoons NO^+ + CO$	8.60e-11	0.00	0	500
1713	2i	$CNO^+ + HCNO \leftrightharpoons CHNO^+ + NCO$	1.06e-09	0.00	0	458
1714	2i	$CO^+ + HCN \leftrightharpoons CHN^+ + CO$	3.06e-09	0.00	0	456
1715	2i	$CO^+ + HCN \leftrightharpoons CHO^+ + CN$	3.40e-10	0.00	0	456
1716	2i	$CO^+ + HNCO \leftrightharpoons CHO^+ + NCO$	2.16e-09	0.00	0	458
1717	2i	$CO^+ + CH_2O \rightleftharpoons CHO^+ + CHO$	1.65e-09	0.00	0	463
1718	2i	$CO^+ + CH_2O \rightleftharpoons CH_2O^+ + CO$	1.35e-09	0.00	0	463
1719	2i	$CO^+ + HCOOH = CHO^+ + CH + O_2$	4.10e-09	0.00	0	443
1720	2i	$CO^+ + CH_4 = CH_4^+ + CO$	7.93e-10	0.00	0	443
1721	2i	$CO^+ + CH_4 \Rightarrow CHO^+ + CH_3$	4.55e-10	0.00	0	443
1722	2i	$CO^+ + CH_4 \leftrightharpoons C_2H_3O^+ + H$	5.20e-11	0.00	0	443

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1723	2i	$CO^+ + CO_2 \leftrightharpoons CO_2^+ + CO$	3.70e-09	0.00	0	502
1724	2i	$CO^+ + C_2H_2O \leftrightharpoons C_2H_2O^+ + CO$	3.20e-11	0.00	0	474
1725	2i	$CO^+ + HC_3N \leftrightharpoons C_3HN^+ + CO$	3.10e-09	0.00	0	479
1726	2i	$CO^+ + H_2 \leftrightharpoons CHO^+ + H$	1.80e-09	0.00	0	463
1727	2i	$CO^+ + H_2O \leftrightharpoons H_2O^+ + CO$	1.72e-09	0.00	0	427
1728	2i	$CO^+ + H_2O \leftrightharpoons CHO^+ + HO$	8.84e-10	0.00	0	427
1729	2i	$CO^+ + H_3N \leftrightharpoons H_3N^+ + CO$	1.20e-09	0.00	0	428
1730	2i	$CO^+ + H_3N \leftrightharpoons CHO^+ + H_2N$	3.00e-10	0.00	0	428
1731	2i	$CO^+ + H_3N \leftrightharpoons CHO^+ + H_2N$	3.00e-10	0.00	0	485
1732	2i	$CO^+ + N \leftrightharpoons NO^+ + C$	1.99e-11	0.00	0	503
1733	2i	$CO^+ + NO \leftrightharpoons NO^+ + CO$	3.30e-10	0.00	0	503
1734	2i	$CO^+ + O \leftrightharpoons O^+ + CO$	1.40e-10	0.00	0	503
1735	2i	$CO^+ + O_2 \leftrightharpoons O_2^+ + CO$	1.20e-10	0.00	0	463
1736	2i	$CO_2^+ + HCN \leftrightharpoons CHN^+ + CO_2$	8.10e-10	0.00	0	456
1737	2i	$CO_2^+ + HCN \leftrightharpoons CHO_2^+ + CN$	9.00e-11	0.00	0	456
1738	2i	$CO_2^+ + CH_4 \leftrightharpoons CH_4^+ + CO_2$	5.50 e-10	0.00	0	471
1739	2i	$CO_2^+ + CH_4 \leftrightharpoons CHO_2^+ + CH_3$	5.50 e-10	0.00	0	471
1740	2i	$CO_2^+ + C_2H_2 \leftrightharpoons C_2H_2^+ + CO_2$	7.30e-11	0.00	0	504
1741	2i	$CO_2^+ + C_2H_4 \leftrightharpoons C_2H_2^+ + CO_2 + H_2$	5.04e-10	0.00	0	505
1742	2i	$CO_2^+ + C_2H_4 \leftrightharpoons C_2H_3^+ + CO_2 + H$	2.43e-10	0.00	0	505
1743	2i	$CO_2^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + CO_2$	1.53e-10	0.00	0	505
1744	2i	$CO_2^+ + H \leftrightharpoons CHO^+ + O$	2.41e-10	0.00	0	506
1745	2i	$CO_2^+ + H \leftrightharpoons H^+ + CO_2$	4.93e-11	0.00	0	506
1746	2i	$CO_2^+ + H_2 \leftrightharpoons CHO_2^+ + H$	1.40e-09	0.00	0	110
1747	2i	$CO_2^+ + H_2O \leftrightharpoons H_2O^+ + CO_2$	2.04e-09	0.00	0	427
1748	2i	$CO_2^+ + H_2O \leftrightharpoons CHO_2^+ + HO$	7.56e-10	0.00	0	427
1749	2i	$CO_2^+ + H_3N \leftrightharpoons H_3N^+ + CO_2$	1.86e-09	0.00	0	428
1750	2i	$CO_2^+ + NO \leftrightharpoons NO^+ + CO_2$	1.20e-10	0.00	0	507
1751	2i	$CO_2^+ + NO_2 \leftrightharpoons NO_2^+ + CO_2$	7.80e-10	0.00	0	508
1752	2i	$CO_2^+ + O \leftrightharpoons O_2^+ + CO$	1.64e-10	0.00	0	507
1753	2i	$CO_2^{+} + O = O^{+} + CO_2$	9.62e-11	0.00	0	507
1754	2i	$CO_2^+ + O_2 \leftrightharpoons O_2^+ + CO_2$	6.30e-11	-1.06	0	509
1755	2i	$C_2^+ + HCN = C_3N^+ + H$	1.56e-09	0.00	0	473
1756	2i	$C_2^{+} + HCN = C_3H^{+} + N$	7.80e-10	0.00	0	473
1757	2i	$C_2^+ + HCN \leftrightharpoons C_2H^+ + CN$	2.60e-10		0	473
1758	2i	$C_2^+ + CH_4 \leftrightharpoons C_3H_2^+ + H_2$	5.74e-10	0.00	0	107
1759	2i	$C_2^+ + CH_4 \leftrightharpoons C_2H^+ + CH_3$	2.38e-10	0.00	0	107
1760	2i	$C_2^+ + CH_4 \leftrightharpoons C_3H_3^+ + H$	2.10e-10	0.00	0	107
1761	2i	$C_2^+ + CH_4 \leftrightharpoons C_3H^+ + H_2 + H$	1.96e-10	0.00	0	107
1762	2i	$C_2^+ + CH_4 \leftrightharpoons C_2H_2^+ + CH_2$	1.82e-10	0.00	0	107
1763	2i	$C_2^+ + C_2H_2 \leftrightharpoons C_4H^+ + H$	1.70e-09	0.00	0	473

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1764	2i	$C_2^+ + NCCN \leftrightharpoons C_2N^+ + C_2N$	7.50e-10	0.00	0	446
1765	2i	$C_2^+ + NCCN \leftrightharpoons C_3N^+ + CN$	4.50e-10	0.00	0	446
1766	2i	$C_2^+ + NCCN \leftrightharpoons C_4^+ + N_2$	3.00e-10	0.00	0	446
1767	2i	$C_2^+ + HC_3N \leftrightharpoons C_3N^+ + C_2H$	2.40e-09	0.00	0	479
1768	2i	$C_2^+ + HC_3N \leftrightharpoons C_5N^+ + H$	9.60 e-10	0.00	0	479
1769	2i	$C_2^+ + HC_3N \leftrightharpoons C_3H^+ + C_2N$	9.60e-10	0.00	0	479
1770	2i	$C_2^+ + H_2 \leftrightharpoons C_2 H^+ + H$	1.40e-09	0.00	0	107
1771	2i	$C_2^+ + N \leftrightharpoons C^+ + CN$	3.99e-11	0.00	0	453
1772	2i	$C_2^+ + NO \leftrightharpoons NO^+ + C_2$	3.40e-10	0.00	0	453
1773	2i	$C_2^+ + O \leftrightharpoons C^+ + CO$	3.10e-10	0.00	0	453
1774	2i	$C_2^+ + O \leftrightharpoons CO^+ + C$	3.10e-10	0.00	0	453
1775	2i	$C_2H^+ + HCN \leftrightharpoons C_2H_2^+ + CN$	1.40e-09	0.00	0	510
1776	2i	$C_2H^+ + HCN \leftrightharpoons CH_2N^+ + C_2$	1.40e-09	0.00	0	510
1777	2i	$C_2H^+ + CH_4 \leftrightharpoons C_2H_2^+ + CH_3$	3.74e-10	0.00	0	107
1778	2i	$C_2H^+ + CH_4 \leftrightharpoons C_3H_3^+ + H_2$	3.74e-10	0.00	0	107
1779	2i	$C_2H^+ + CH_4 \leftrightharpoons C_3H_4^+ + H$	1.32e-10	0.00	0	107
1780	2i	$C_2H^+ + C_2H_2 \leftrightharpoons C_2H_3^+ + C_2$	2.40e-09	0.00	0	451
1781	2i	$C_2H^+ + C_2H_2 \leftrightharpoons C_4H_2^+ + H$	2.40e-09	0.00	0	451
1782	2i	$C_2H^+ + C_2H_4 \leftrightharpoons C_4H_3^+ + H_2$	5.80e-10	0.00	0	511
1783	2i	$C_2H^+ + HC_3N \leftrightharpoons C_3H_2N^+ + C_2$	1.60e-09	0.00	0	479
1784	2i	$C_2H^+ + HC_3N \leftrightharpoons C_4H_2^+ + CN$	6.40 e-10	0.00	0	479
1785	2i	$C_2H^+ + HC_3N \leftrightharpoons C_5HN^+ + H$	6.40 e-10	0.00	0	479
1786	2i	$C_2H^+ + HC_3N \leftrightharpoons C_3HN^+ + C_2H$	3.20e-10	0.00	0	479
1787	2i	$C_2H^+ + H_2 \leftrightharpoons C_2H_2^+ + H$	1.70e-09	0.00	0	107
1788	2i	$C_2H^+ + N \leftrightharpoons CH^+ + CN$	9.00e-11	0.00	0	453
1789	2i	$C_2H^+ + NO = NO^+ + C_2H$	1.20e-10	0.00	0	453
1790	2i	$C_2H^+ + O \leftrightharpoons C^+ + CHO$	3.30e-10	0.00	0	453
1791	2i	$C_2H^+ + O \leftrightharpoons CH^+ + CO$	3.30e-10	0.00	0	453
1792	2i	$C_2H^+ + O \leftrightharpoons CHO^+ + C$	3.30e-10	0.00	0	453
1793	2i	$C_2H^+ + O = CO^+ + CH$	3.30e-10	0.00	0	453
1794	2i	$C_2HN^+ + HCN \leftrightharpoons C_3HN_2^+ + H$	1.40e-11	0.00	0	441
1795	2i	$C_2HN_2^+ + CH_3OH \Rightarrow CH_5O^+ + NCCN$	1.50e-09	0.00	0	469
1796	2i	$C_2HN_2^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + NCCN$	3.92e-10	0.00	0	469
1797	2i	$C_2HN_2^+ + H_2O \Longrightarrow H_3O^+ + NCCN$	5.10e-10	0.00	0	469
1798	2i	$C_2H_2^+ + HCN \leftrightharpoons CH_2N^+ + C_2H$	2.34e-10	0.00	0	510
1799	2i	$C_2H_2^+ + HCN \leftrightharpoons C_3H_2N^+ + H$	1.26e-10	0.00	0	510
1800	2i	$C_2H_2^+ + CH_4 \leftrightharpoons C_3H_5^+ + H$	7.80e-10	0.00	0	107
1801	2i	$C_2H_2^+ + CH_4 \leftrightharpoons C_3H_4^+ + H_2$	2.20e-10	0.00	0	107
1802	2i	$C_2H_2^+ + C_2H_2 \leftrightharpoons C_4H_3^+ + H$	1.25e-09	0.00	0	486
1803	2i	$C_2H_2^+ + C_2H_2 \leftrightharpoons C_4H_2^+ + H_2$	1.25e-09	0.00	0	486
1804	2i	$C_2H_2^+ + C_2H_2 \leftrightharpoons C_2H_3^+ + C_2H$	1.25e-09	0.00	0	486

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1805	2i	$C_2H_2^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + C_2H_2$	8.96e-10	0.00	0	512
1806	2i	$C_2H_2^+ + C_2H_4 \leftrightharpoons C_3H_3^+ + CH_3$	2.80e-10	0.00	0	512
1807	2i	$C_2H_2^+ + C_2H_4 \leftrightharpoons C_4H_5^+ + H$	2.24e-10	0.00	0	512
1808	2i	$C_2H_2^+ + HC_3N \leftrightharpoons C_4H_2^+ + HCN$	1.60e-09	0.00	0	479
1809	2i	$C_2H_2^+ + H_2 \leftrightharpoons C_2H_3^+ + H$	1.00e-11	0.00	0	107
1810	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons Si^+ + C_2H_6$	1.79e-09	0.00	0	513
1811	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons SiH^+ + C_2H_5$	1.79e-09	0.00	0	513
1812	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons SiH_2^+ + C_2H_4$	1.79e-09	0.00	0	513
1813	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons SiH_3^+ + C_2H_3$	1.79e-09	0.00	0	513
1814	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons SiCH_3^+ + CH_3$	1.79e-09	0.00	0	513
1815	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons SiC_2H^+ + H_2 + H_2 + H$	1.79e-09	0.00	0	513
1816	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons SiC_2H_3^+ + H_2 + H$	1.79e-09	0.00	0	513
1817	2i	$C_2H_2^+ + SiH_4 \leftrightharpoons SiC_2H_5^+ + H$	1.79e-09	0.00	0	513
1818	2i	$C_2H_2^+ + N \leftrightharpoons C_2HN^+ + H$	1.50e-10	0.00	0	453
1819	2i	$C_2H_2^+ + N \leftrightharpoons C_2N^+ + H_2$	7.50e-11	0.00	0	453
1820	2i	$C_2H_2^+ + N \leftrightharpoons CH^+ + HCN$	2.50e-11	0.00	0	453
1821	2i	$C_2H_2^+ + NO \leftrightharpoons NO^+ + C_2H_2$	1.20e-10	0.00	0	453
1822	2i	$C_2H_2^+ + O \leftrightharpoons CHO^+ + CH$	8.50e-11	0.00	0	453
1823	2i	$C_2H_2^+ + O \leftrightharpoons C_2HO^+ + H$	8.50e-11	0.00	0	453
1824	2i	$C_2H_2O^+ + C_2H_2O \leftrightharpoons C_3H_4O^+ + CO$	3.84e-10	0.00	0	514
1825	2i	$C_2H_2O^+ + C_2H_2O \leftrightharpoons C_2H_4^+ + CO + CO$	1.42e-10	0.00	0	514
1826	2i	$C_2H_2O^+ + C_2H_2O \leftrightharpoons C_2H_3O^+ + CHO + C$	6.49e-11	0.00	0	514
1827	2i	$C_2H_3^+ + HCN \leftrightharpoons CH_2N^+ + C_2H_2$	2.90e-09	0.00	0	510
1828	2i	$C_2H_3^+ + CH_4 \leftrightharpoons C_3H_5^+ + H_2$	1.70e-10	0.00	0	107
1829	2i	$C_2H_3^+ + C_2H_2 \leftrightharpoons C_4H_3^+ + H_2$	2.16e-10	0.00	0	473
1830	2i	$C_2H_3^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + C_2H_2$	3.80e-10	0.00	0	515
1831	2i	$C_2H_3^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + C_2H_4$	4.80e-10	0.00	0	516
1832	2i	$C_2H_3^+ + NCCN \leftrightharpoons C_2HN_2^+ + C_2H_2$	4.00e-10	0.00	0	469
1833	2i	$C_2H_3^+ + H_2 \leftrightharpoons C_2H_4^+ + H$	9.99e-13	0.00	0	517
1834	2i	$C_2H_3^+ + SiH_4 \leftrightharpoons SiH_3^+ + C_2H_4$	2.49e-10	0.00	0	518
1835	2i	$C_2H_3^+ + SiH_4 \leftrightharpoons SiH_5^+ + C_2H_2$	3.08e-11	0.00	0	518
1836	2i	$C_2H_3N^+ + CH_3CN \rightleftharpoons C_2H_4N^+ + CH_2CN$	1.96e-09	0.00	0	489
1837	2i	$C_2H_3O^+ + C_2H_4O \leftrightharpoons C_2H_5O^+ + C_2H_2O$	7.14e-10	0.00	0	519
1838	2i	$C_2H_3O^+ + H_3N \leftrightharpoons H_4N^+ + C_2H_2O$	4.99e-11	0.00	0	470
1839	2i	$C_2H_4^+ + C_2H_2 \leftrightharpoons C_3H_3^+ + CH_3$	6.73 e-10	0.00	0	512
1840	2i	$C_2H_4^+ + C_2H_2 \leftrightharpoons C_4H_5^+ + H$	2.37e-10	0.00	0	512
1841	2i	$C_2H_4^+ + C_2H_4 \leftrightharpoons C_3H_5^+ + CH_3$	3.29e-10	0.00	0	520
1842	2i	$C_2H_4^+ + C_2H_4 \leftrightharpoons C_4H_7^+ + H$	1.53e-10	0.00	0	520
1843	2i	$C_2H_4^+ + C_2H_4 \leftrightharpoons C_4H_7^+ + H$	1.53e-10	0.00	0	520
1844	2i	$C_2H_4^+ + C_2H_6 \leftrightharpoons C_3H_7^+ + CH_3$	8.40e-10	0.00	1960	521
1845	2i	$C_2H_4^+ + SiH_4 \leftrightharpoons SiH_2^+ + C_2H_6$	1.41e-09	0.00	0	518

Table 6—Continued

		TABLE 0—Continued				
#	Type	Reaction	α	β	γ	Ref
1846	2i	$C_2H_4^+ + SiH_4 \leftrightharpoons SiH_3^+ + C_2H_5$	1.41e-09	0.00	0	518
1847	2i	$C_2H_4^+ + SiH_4 \leftrightharpoons SiC_2H_4^+ + H_2 + H_2$	1.41e-09	0.00	0	518
1848	2i	$C_2H_4^{\uparrow} + SiH_4 = SiC_2H_5^{\uparrow} + H_2 + H$	1.41e-09	0.00	0	518
1849	2i	$C_2H_4^{\uparrow} + SiH_4 = SiC_2H_6^{\uparrow} + H_2$	1.41e-09	0.00	0	518
1850	2i	$C_2H_4^+ + NO = NO^+ + C_2H_4$	3.60e-10	0.00	0	487
1851	2i	$C_2H_4N^+ + CH_3OH \Rightarrow C_3H_6N^+ + H_2O$	2.70e-11	0.00	0	522
1852	2i	$C_2H_4N^+ + CH_3CN \leftrightharpoons C_3H_6N^+ + HCN$	6.30e-11	0.00	0	523
1853	2i	$C_2H_4O^+ + C_2H_4O \leftrightharpoons C_2H_5O^+ + C_2H_3O$	2.95e-09	0.00	0	466
1854	2i	$C_2H_4O^+ + H_3N \leftrightharpoons H_4N^+ + C_2H_3O$	1.20e-10	0.00	0	470
1855	2i	$C_2H_5^+ + HCN \leftrightharpoons CH_2N^+ + C_2H_4$	2.70e-09	0.00	0	510
1856	2i	$C_2H_5^+ + CH_2O \leftrightharpoons CH_3O^+ + C_2H_4$	3.10e-09	0.00	0	524
1857	2i	$C_2H_5^+ + HCOOH \Rightarrow CH_3O_2^+ + C_2H_4$	1.50e-09	0.00	0	443
1858	2i	$C_2H_5^+ + C_2H_2 \leftrightharpoons C_4H_5^+ + H_2$	1.24e-10	0.00	0	473
1859	2i	$C_2H_5^+ + C_2H_2 \leftrightharpoons C_3H_3^+ + CH_4$	$6.65 e{\text{-}}11$	0.00	0	473
1860	2i	$C_2H_5^+ + C_2H_4 \leftrightharpoons C_3H_5^+ + CH_4$	6.10e-10	0.00	0	111
1861	2i	$C_2H_5^+ + C_2H_6 = C_4H_9^+ + H_2$	3.44e-11	0.00	0	525
1862	2i	$C_2H_5^+ + C_2H_6 \rightleftharpoons C_3H_7^+ + CH_4$	5.60e-12	0.00	0	525
1863	2i	$C_2H_5^+ + H_2 = C_2H_6^+ + H$	7.30e-14	0.00	589	Est
1864	2i	$C_2H_5^+ + H_3N = H_4N^+ + C_2H_4$	2.10e-09	0.00	0	497
1865	2i	$C_2H_5O^+ + (CH_3)_2O = C_3H_9O^+ + CH_2O$	2.60e-11	0.00	0	499
1866	2i	$C_2H_5O^+ + H_3N = H_4N^+ + C_2H_4O$	4.73e-10	0.00	0	470
1867	2i	$C_2H_5O_2^+ + C_2H_4O = C_2H_5O^+ + CH_3COOH$	2.43e-09	0.00	0	519
1868	2i	$C_2H_5O_2^+ + C_2H_4O = C_4H_7O_2^+ + H_2O$	8.42e-10	0.00	0	519
1869	2i	$C_2H_6^+ + C_2H_6 \leftrightharpoons C_3H_8^+ + CH_4$	1.01e-10	0.00	0	526
1870	2i	$C_2H_6^+ + C_2H_6 \leftrightharpoons C_4H_9^+ + H_2 + H$	1.01e-10	0.00	0	526
1871	2i	$C_2H_6^+ + C_2H_6 \leftrightharpoons C_3H_9^+ + CH_3$	1.01e-10	0.00	0	526
1872	2i	$C_2H_6^+ + C_2H_6 \leftrightharpoons C_3H_7^+ + CH_4 + H$	1.01e-10	0.00	0	526
1873	2i	$C_2H_6^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + C_2H_6 + H$	1.01e-10	0.00	0	526
1874	2i	$C_2H_6^+ + H_2O \leftrightharpoons H_3O^+ + C_2H_5$	1.20e-09	0.00	0	527
1875	2i	$C_2H_6^+ + O_2 = C_2H_5^+ + HO_2$	1.15e-10	0.00	0	528
1876	2i	$C_2H_6O^+ + (CH_3)_2O = C_2H_7O^+ + CH_3OCH_2$	1.93e-09	0.00	0	489
1877	2i	$C_2H_6O^+ + H_3N \leftrightharpoons H_4N^+ + CH_3CH_2O$	8.43e-10	0.00	0	470
1878	2i	$C_2H_7^+ + HCN \leftrightharpoons CH_2N^+ + C_2H_6$	1.98e-09	0.00	0	510
1879	2i	$C_2H_7^+ + HCN \leftrightharpoons C_2H_4N^+ + CH_4$	2.20e-10	0.00	0	510
1880	2i	$C_2H_7^+ + H_3N \leftrightharpoons H_4N^+ + C_2H_6$	2.00e-09	0.00	0	497
1881	2i	$C_2H_7O^+ + HCN \rightleftharpoons C_3H_6N^+ + H_2O$	1.50e-11	0.00	0	522
1882	2i	$C_2H_7O^+ + HCN \leftrightharpoons C_2H_4N^+ + CH_3OH$	1.80e-11	0.00	0	522
1883	2i	$C_2H_7O^+ + CH_2O = C_3H_7O^+ + H_2O$	1.70e-11	0.00	0	499
1884	2i	$C_2H_7O^+ + CH_3CN \leftrightharpoons C_3H_6N^+ + CH_3OH$	7.20e-11	0.00	0	522
1885	2i	$C_2H_7O^+ + (CH_3)_2O = C_3H_9O^+ + CH_3OH$	1.20e-11	0.00	0	499
		$C_2N^+ + HCN \rightleftharpoons C_3N_2^+ + H$	1.50e-11	0.00		

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1887	2i	$C_2N^+ + CH_4 \leftrightharpoons C_2H_3^+ + HCN$	2.64e-12	0.00	0	454
1888	2i	$C_2N^+ + CH_4 \leftrightharpoons C_3H_2N^+ + H_2$	1.32e-12	0.00	0	454
1889	2i	$C_2N^+ + CH_4 \leftrightharpoons CH_2N^+ + C_2H_2$	4.40e-13	0.00	0	454
1890	2i	$C_2N^+ + C_2H_2 \leftrightharpoons C_3H^+ + HCN$	8.01e-10	0.00	0	501
1891	2i	$C_2N^+ + C_2H_4 \leftrightharpoons C_2H_2N^+ + C_2H_2$	5.85e-10	0.00	0	501
1892	2i	$C_2N^+ + C_2H_4 \leftrightharpoons C_3H_3^+ + HCN$	3.51e-10	0.00	0	501
1893	2i	$C_2N^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + C_2N$	1.17e-10	0.00	0	501
1894	2i	$C_2N^+ + C_2H_4 \leftrightharpoons C_4H_2N^+ + H_2$	1.17e-10	0.00	0	501
1895	2i	$C_2N^+ + C_2H_6 \leftrightharpoons C_3H_3^+ + HCN + H_2$	3.60e-10	0.00	0	501
1896	2i	$C_2N^+ + C_2H_6 \leftrightharpoons C_2H_2N^+ + C_2H_4$	3.00e-10	0.00	0	501
1897	2i	$C_2N^+ + C_2H_6 \leftrightharpoons C_2H_3^+ + CH_3CN$	1.20e-10	0.00	0	501
1898	2i	$C_2N^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + HCCN$	1.20e-10	0.00	0	501
1899	2i	$C_2N^+ + HC_3N \leftrightharpoons C_3H^+ + NCCN$	3.10e-09	0.00	0	479
1900	2i	$C_2N^+ + H_2O \leftrightharpoons CHO^+ + HCN$	2.55e-10	0.00	0	501
1901	2i	$C_2N^+ + H_2O \leftrightharpoons C_2HN^+ + HO$	8.50e-11	0.00	0	501
1902	2i	$C_2N^+ + H_3N \leftrightharpoons CH_2N^+ + HCN$	1.71e-09	0.00	0	501
1903	2i	$C_2N^+ + H_3N \leftrightharpoons HN_2^+ + C_2H_2$	1.90e-10	0.00	0	501
1904	2i	$C_2N_2^+ + HCN \leftrightharpoons C_3N_3^+ + H$	1.60e-11	0.00	0	441
1905	2i	$C_2N_2^+ + HC_3N \leftrightharpoons C_3HN^+ + NCCN$	1.60e-09	0.00	0	479
1906	2i	$H^+ + HCN \leftrightharpoons CHN^+ + H$	1.10e-09	0.00	0	529
1907	2i	$\mathrm{H}^+ + \mathrm{CH}_4 \leftrightarrows \mathrm{CH}_3^+ + \mathrm{H}_2$	4.50e-09	0.00	0	525
1908	2i	$\mathrm{H^+} + \mathrm{CH_4} \leftrightarrows \mathrm{CH_4^+} + \mathrm{H}$	4.50e-09	0.00	0	525
1909	2i	$H^+ + CO_2 \leftrightharpoons CHO^+ + O$	3.00e-09	0.00	0	506
1910	2i	$\mathrm{H}^{+} + \mathrm{C}_{2}\mathrm{H}_{6} \leftrightharpoons \mathrm{C}_{2}\mathrm{H}_{4}^{+} + \mathrm{H}_{2} + \mathrm{H}$	3.90e-09	0.00	0	467
1911	2i	$\mathrm{H}^{+} + \mathrm{C}_{2}\mathrm{H}_{6} \leftrightharpoons \mathrm{C}_{2}\mathrm{H}_{3}^{+} + \mathrm{H}_{2} + \mathrm{H}_{2}$	3.90e-09	0.00	0	467
1912	2i	$H^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + H_2$	3.90e-09	0.00	0	467
1913	2i	$H^+ + NO = NO^+ + H$	1.90e-09	0.00	0	530
1914	2i	$H^+ + O \leftrightharpoons O^+ + H$	3.75e-10	0.00	0	530
1915	2i	$HN^+ + CH_2O \leftrightharpoons CHO^+ + H_2N$	1.82e-09	0.00	0	531
1916	2i	$HN^+ + CH_2O \rightleftharpoons CH_2O^+ + HN$	9.90e-10	0.00	0	531
1917	2i	$HN^+ + CH_2O \rightleftharpoons CH_3O^+ + N$	4.95e-10	0.00	0	531
1918	2i	$HN^+ + CH_4 \leftrightharpoons CH_2N^+ + H_2 + H$	6.72e-10	0.00	0	531
1919	2i	$HN^+ + CH_4 \leftrightharpoons H_2N^+ + CH_3$	1.92e-10	0.00	0	531
1920	2i	$HN^+ + CH_4 \leftrightharpoons CH_5^+ + N$	9.60e-11	0.00	0	531
1921	2i	$HN^+ + CH_3OH \Rightarrow CH_3O^+ + H_2N$	2.10e-09		0	531
1922	2i	$HN^+ + CH_3OH = CHO^+ + H_3N + H$	4.50e-10	0.00	0	531
1923	2i	$HN^+ + CH_3OH \Rightarrow CH_2O^+ + H_3N$	4.50e-10	0.00	0	531
1924	2i	$HN^+ + CH_3OH = CH_5O^+ + N$	2.10e-10	0.00	0	531
1925	2i	$HN^+ + CH_5N \Rightarrow CH_4N^+ + H_2N$	9.45e-10	0.00	0	531
1926	2i	$HN^+ + CH_5N \leftrightharpoons CH_5N^+ + HN$	4.20e-10	0.00	0	531
1927	2i	$HN^+ + CH_5N \leftrightharpoons CH_6N^+ + N$	4.20e-10	0.00	0	531

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
1928	2i	$HN^+ + CH_5N \leftrightharpoons CH_2N^+ + H_3N + H$	4.20e-10	0.00	0	531
1929	2i	$HN^+ + CH_5N \leftrightharpoons CH_3N^+ + H_3N$	1.05e-10	0.00	0	531
1930	2i	$HN^+ + CO \leftrightharpoons CNO^+ + H$	5.39e-10	0.00	0	531
1931	2i	$HN^+ + CO \leftrightharpoons CHO^+ + N$	4.41e-10	0.00	0	531
1932	2i	$HN^+ + CO_2 \leftrightharpoons CHO_2^+ + N$	3.85e-10	0.00	0	531
1933	2i	$HN^+ + CO_2 \leftrightharpoons HNO^+ + CO$	3.85e-10	0.00	0	531
1934	2i	$HN^+ + CO_2 \leftrightharpoons NO^+ + CHO$	3.30e-10	0.00	0	531
1935	2i	$HN^+ + C_2H_4 \leftrightharpoons C_2H_3^+ + H_2N$	3.75e-10	0.00	0	532
1936	2i	$HN^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + HN$	3.75e-10	0.00	0	532
1937	2i	$HN^+ + C_2H_4 \leftrightharpoons CH_2N^+ + CH_3$	3.00e-10	0.00	0	532
1938	2i	$HN^+ + C_2H_4 \leftrightharpoons C_2H_2^+ + H_3N$	1.50e-10	0.00	0	532
1939	2i	$HN^+ + C_2H_4 \leftrightharpoons CH_3N^+ + CH_2$	1.50e-10	0.00	0	532
1940	2i	$HN^+ + C_2H_4 \leftrightharpoons C_2H_3N^+ + H_2$	1.50e-10	0.00	0	532
1941	2i	$HN^+ + H_2 \leftrightharpoons H_2N^+ + H$	1.28e-09	0.00	0	531
1942	2i	$HN^+ + H_2 \leftrightharpoons H_3^+ + N$	2.25e-10	0.00	0	531
1943	2i	$HN^+ + H_2O \leftrightharpoons H_3O^+ + N$	1.05e-09	0.00	0	531
1944	2i	$HN^+ + H_2O \leftrightharpoons H_2O^+ + HN$	1.05e-09	0.00	0	531
1945	2i	$HN^+ + H_2O \leftrightharpoons H_2N^+ + HO$	8.75e-10	0.00	0	531
1946	2i	$HN^+ + H_2O \leftrightharpoons HNO^+ + H_2$	3.50e-10	0.00	0	531
1947	2i	$HN^+ + H_3N \leftrightharpoons H_3N^+ + HN$	1.80e-09	0.00	0	531
1948	2i	$HN^+ + H_3N \leftrightharpoons H_4N^+ + N$	6.00e-10	0.00	0	531
1949	2i	$HN^+ + NO \leftrightharpoons NO^+ + HN$	7.12e-10	0.00	0	531
1950	2i	$HN^+ + NO \leftrightharpoons HN_2^+ + O$	1.78e-10	0.00	0	531
1951	2i	$HN^+ + N_2 \leftrightharpoons HN_2^+ + N$	6.50 e-10	0.00	0	531
1952	2i	$HN^+ + O_2 \leftrightharpoons O_2^+ + HN$	4.51e-09	0.00	0	531
1953	2i	$HN^+ + O_2 \leftrightharpoons NO^+ + HO$	2.05e-09	0.00	0	531
1954	2i	$HN^+ + O_2 \leftrightharpoons HO_2^+ + N$	1.64e-09	0.00	0	531
1955	2i	$HNO^+ + CH_4 \leftrightharpoons CH_5^+ + NO$	1.01e-10	0.00	0	433
1956	2i	$HNO^+ + CO \leftrightharpoons CHO^+ + NO$	1.01e-10	0.00	0	433
1957	2i	$HNO^+ + CO_2 \leftrightharpoons CHO_2^+ + NO$	1.01e-10	0.00	0	433
1958	2i	$HNO^+ + H_2O \leftrightharpoons H_3O^+ + NO$	2.30e-09	0.00	0	436
1959	2i	$HNO^+ + NO \leftrightharpoons NO^+ + HNO$	7.00e-10	0.00	0	111
1960	2i	$HNO^+ + N_2 \leftrightharpoons HN_2^+ + NO$	9.99e-12	0.00	0	433
1961	2i	$HN_2^+ + HCN \leftrightharpoons CH_2N^+ + N_2$	3.20e-09	0.00	0	465
1962	2i	$HN_2^+ + CH_2O \leftrightharpoons CH_3O^+ + N_2$	3.30e-09	0.00	0	490
1963	2i	$HN_2^+ + CH_3NO_2 \leftrightharpoons CH_4NO_2^+ + N_2$	3.27e-09	0.00	0	462
1964	2i	$HN_2^+ + CH_3NO_2 \leftrightharpoons NO^+ + CH_3OH + N_2$	1.65e-11	0.00	0	462
1965	2i	$HN_2^+ + CH_4 \leftrightharpoons CH_5^+ + N_2$	8.90e-10	0.00	0	111
1966	2i	$HN_2^+ + CO \leftrightharpoons CHO^+ + N_2$	8.79e-10	0.00	0	533
1967	2i	$HN_2^+ + CO_2 \leftrightharpoons CHO_2^+ + N_2$	9.80e-10	0.00	0	534
1968	2i	$HN_2^{+} + C_2H_2 \leftrightharpoons C_2H_3^{+} + N_2$	1.41e-09	0.00	0	464

Table 6—Continued

		TABLE 0—Continued				
#	Type	Reaction	α	β	γ	Ref
1969	2i	$HN_2^+ + CH_3CN \leftrightharpoons C_2H_4N^+ + N_2$	4.10e-09	0.00	0	465
1970	2i	$HN_2^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + H_2N_2$	1.13e-09	0.00	0	467
1971	2i	$HN_2^+ + C_2H_6 \leftrightharpoons C_2H_7^+ + N_2$	1.69e-10	0.00	0	467
1972	2i	$HN_2^+ + NCCN \leftrightharpoons C_2HN_2^+ + N_2$	1.20e-09	0.00	0	469
1973	2i	$HN_2^+ + HC_3N \leftrightharpoons C_3H_2N^+ + N_2$	4.20e-09	0.00	0	469
1974	2i	$HN_2^{+} + H_2O \leftrightharpoons H_3O^{+} + N_2$	5.50e-09	0.00	0	535
1975	2i	$HN_2^{+} + H_3N \leftrightharpoons H_4N^+ + N_2$	2.30e-09	0.00	0	497
1976	2i	$HN_2^+ + NO \leftrightharpoons HNO^+ + N_2$	3.40e-10	0.00	0	436
1977	2i	$HN_2^{+} + N_2O \leftrightharpoons HN_2O^{+} + N_2$	7.90e-10	0.00	0	111
1978	2i	$HN_2^+ + O_2(a^1\Delta_q) \leftrightharpoons HO_2^+ + N_2$	8.00e-11	0.00	0	536
1979	2i	$HN_2O^+ + CH_3NO_2 \leftrightharpoons CH_4NO_2^+ + N_2O$	2.70e-09	0.00	0	462
1980	2i	$HN_2O^+ + CH_3NO_2 = NO^+ + CH_3OH + N_2O$	1.62e-12	0.00	0	462
1981	2i	$HN_2O^+ + C_2H_2 \leftrightharpoons C_2H_3^+ + N_2O$	1.21e-09	0.00	0	464
1982	2i	$HN_2O^+ + CH_3CN = C_2H_4N^+ + N_2O$	3.80e-09	0.00	0	465
1983	2i	$HN_2O^+ + C_2H_6 \leftrightharpoons C_2H_7^+ + N_2O$	1.05e-09	0.00	0	467
1984	2i	$HN_2O^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + N_2O + H_2$	5.50e-11	0.00	0	467
1985	2i	$HN_2O^+ + H_2O \rightleftharpoons H_3O^+ + N_2O$	2.80e-09	0.00	0	472
1986	2i	$HN_2O^+ + H_3N \leftrightharpoons H_4N^+ + N_2O$	2.10e-09	0.00	0	497
1987	2i	$\mathrm{HO^{+}} + \mathrm{CH_{4}} \leftrightharpoons \mathrm{H_{3}O^{+}} + \mathrm{CH_{2}}$	1.31e-09	0.00	0	492
1988	2i	$HO^+ + CH_4 \leftrightharpoons CH_5^+ + O$	1.95e-10	0.00	0	492
1989	2i	$HO^+ + CO = CHO^+ + O$	8.20e-10	0.00	0	492
1990	2i	$HO^+ + CO_2 \leftrightharpoons CHO_2^+ + O$	1.44e-09	0.00	0	537
1991	2i	$HO^{+} + C_{2}H_{6} = C_{2}H_{4}^{+} + H_{2}O + H$	1.04e-09	0.00	0	467
1992	2i	$\mathrm{HO^{+} + C_{2}H_{6} \leftrightharpoons C_{2}H_{5}^{+} + H_{2}O}$	3.20e-10	0.00	0	467
1993	2i	$HO^{+} + C_{2}H_{6} = H_{3}O^{+} + C_{2}H_{4}$	1.60e-10	0.00	0	467
1994	2i	$HO^{+} + C_{2}H_{6} = C_{2}H_{6}^{+} + HO$	4.80e-11	0.00	0	467
1995	2i	$HO^{+} + C_{2}H_{6} = C_{2}H_{7}^{+} + O$	3.20e-11	0.00	0	467
1996	2i	$HO^+ + H_2 \leftrightharpoons H_2O^+ + H$	1.50e-09	0.00	0	110
1997	2i	$\mathrm{HO^{+}} + \mathrm{H_{2}O} \leftrightharpoons \mathrm{H_{2}O^{+}} + \mathrm{HO}$	2.87e-09	0.00	0	538
1998	2i	$\mathrm{HO^{+}} + \mathrm{H_{2}O} \leftrightharpoons \mathrm{H_{3}O^{+}} + \mathrm{O}$	2.87e-09	0.00	0	538
1999	2i	$HO^+ + NO = HNO^+ + O$	6.11e-10	0.00	0	537
2000	2i	$HO^+ + NO = NO^+ + HO$	3.59e-10	0.00	0	537
2001	2i	$HO^+ + NO_2 = NO_2^+ + HO$	1.30e-09	0.00	0	539
2002	2i	$HO^+ + N_2 \stackrel{-}{\rightleftharpoons} HN_2^+ + O$	3.60e-10	0.00	0	537
2003	2i	$HO^+ + N_2O \rightleftharpoons HN_2O^+ + O$	1.12e-09	0.00	0	537
2004	2i	$\mathrm{HO^{+}} + \mathrm{N_{2}O} \leftrightarrows \mathrm{N_{2}O^{+}} + \mathrm{HO}$	2.50e-10	0.00	0	537
2005	2i	$HO^+ + N_2O = NO^+ + HNO$	1.72e-10	0.00	0	537
2006	2i	$\mathrm{HO^{+}} + \mathrm{O_{2}} \leftrightharpoons \mathrm{O_{2}^{+}} + \mathrm{HO}$	2.00e-10	0.00	0	110
2007	2i	$HO_2^+ + Ar \leftrightharpoons ArH^+ + O_2$	1.90e-11	0.00	0	435
2008	2i	$\mathrm{HO}_2^+ + \mathrm{CO}_2 \leftrightharpoons \mathrm{CHO}_2^+ + \mathrm{O}_2$	1.10e-09	0.00	0	496
2000						

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2010	2i	$HO_2^+ + H_3N \leftrightharpoons H_4N^+ + O_2$	2.00e-09	0.00	0	496
2011	2i	$HO_2^+ + NO \leftrightharpoons HNO^+ + O_2$	7.30e-10	0.00	0	541
2012	2i	$HO_2^+ + NO \leftrightharpoons NO^+ + HO_2$	7.30e-10	0.00	0	541
2013	2i	$HO_2^+ + N_2 \leftrightharpoons HN_2^+ + O_2$	8.00e-10	0.00	0	496
2014	2i	$SiH^{+} + SiH_{4} \leftrightharpoons Si_{2}H^{+} + H_{2} + H_{2}$	1.20e-10	0.00	0	542
2015	2i	$SiH^+ + SiH_4 \leftrightharpoons Si_2H_2^+ + H_2 + H$	5.20e-11	0.00	0	542
2016	2i	$SiH^+ + Si_2H_6 \leftrightharpoons Si_3H_5^+ + H_2$	3.80e-10	0.00	0	543
2017	2i	$SiH^+ + Si_2H_6 \leftrightharpoons Si_2H_3^+ + SiH_4$	3.30e-10	0.00	0	543
2018	2i	$SiH^+ + Si_2H_6 \leftrightharpoons Si_3H_3^+ + H_2 + H_2$	1.80e-10	0.00	0	543
2019	2i	$SiH^+ + Si_2H_6 \leftrightharpoons Si_2H^+ + SiH_4 + H_2$	1.10e-10	0.00	0	543
2020	2i	$\mathrm{Si}_{2}\mathrm{H}^{+}+\mathrm{Si}_{2}\mathrm{H}_{6} \leftrightharpoons \mathrm{Si}_{4}\mathrm{H}_{3}^{+}+\mathrm{H}_{2}+\mathrm{H}_{2}$	3.19e-10	0.00	0	543
2021	2i	$Si_2H^+ + Si_2H_6 \leftrightharpoons Si_4H_5^+ + H_2$	1.73e-10	0.00	0	543
2022	2i	$\mathrm{Si}_{2}\mathrm{H}^{+} + \mathrm{Si}_{2}\mathrm{H}_{6} \leftrightharpoons \mathrm{Si}_{3}\mathrm{H}_{3}^{+} + \mathrm{SiH}_{4}$	4.86e-11	0.00	0	543
2023	2i	$Si_2H^+ + Si_2H_6 \leftrightharpoons Si_3H_3^+ + SiH_4$	4.86e-11	0.00	0	543
2024	2i	$\mathrm{H}_2^+ + \mathrm{CO}_2 \leftrightharpoons \mathrm{CHO}_2^+ + \mathrm{H}$	2.35e-09	0.00	0	544
2025	2i	$H_2^+ + H \leftrightharpoons H^+ + H_2$	6.40 e-10	0.00	0	545
2026	2i	$H_2^+ + H_2 \leftrightharpoons H_3^+ + H$	2.11e-09	0.00	0	546
2027	2i	$H_2^+ + He \leftrightharpoons HeH^+ + H$	1.40e-10	0.00	0	547
2028	2i	$H_2^+ + O_2 \leftrightharpoons HO_2^+ + H$	7.56e-09	0.00	0	548
2029	2i	$H_2N^+ + CH_2O \leftrightharpoons CH_3O^+ + HN$	2.24e-09	0.00	0	531
2030	2i	$H_2N^+ + CH_2O \leftrightharpoons H_3N^+ + CHO$	5.60e-10	0.00	0	531
2031	2i	$H_2N^+ + HCOOH \leftrightharpoons H_4N^+ + CO_2$	2.70e-09	0.00	0	443
2032	2i	$H_2N^+ + CH_4 \leftrightharpoons H_3N^+ + CH_3$	9.20e-10	0.00	0	531
2033	2i	$H_2N^+ + CH_3OH \leftrightharpoons CH_5O^+ + HN$	2.64e-09	0.00	0	531
2034	2i	$H_2N^+ + CH_3OH \leftrightharpoons H_3N^+ + CHO + H_2$	4.65e-10	0.00	0	531
2035	2i	$H_2N^+ + CH_5N \leftrightharpoons CH_5N^+ + H_2N$	9.00e-10	0.00	0	549
2036	2i	$H_2N^+ + CH_5N \leftrightharpoons CH_6N^+ + HN$	3.60e-10	0.00	0	549
2037	2i	$H_2N^+ + CH_5N \leftrightharpoons CH_4N^+ + H_3N$	3.60e-10	0.00	0	549
2038	2i	$H_2N^+ + CH_5N \leftrightharpoons H_4N^+ + CH_3N$	1.80e-10	0.00	0	549
2039	2i	$H_2N^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + H_2N$	4.50e-10	0.00	0	532
2040	2i	$H_2N^+ + C_2H_4 \leftrightharpoons CH_4N^+ + CH_2$	4.50e-10	0.00	0	532
2041	2i	$H_2N^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + HN$	3.00e-10	0.00	0	532
2042	2i	$H_2N^+ + C_2H_4 \leftrightharpoons C_2H_5N^+ + H$	3.00e-10	0.00	0	532
2043	2i	$H_2N^+ + H_2 \leftrightharpoons H_3N^+ + H$	1.00e-09	0.00	0	110
2044	2i	$H_2N^+ + H_2O \rightleftharpoons H_3O^+ + HN$	2.76e-09		0	531
2045	2i	$H_2N^+ + H_2O \leftrightharpoons H_4N^+ + O$	1.45e-10	0.00	0	531
2046	2i	$H_2N^+ + H_3N \leftrightharpoons H_4N^+ + HN$	1.10e-09	0.00	0	550
2047	2i	$H_2N^+ + H_3N \leftrightharpoons H_3N^+ + H_2N$	1.10e-09	0.00	0	550
2048	2i	$H_2N^+ + NO \leftrightharpoons NO^+ + H_2N$	7.00e-10	0.00	0	531
2049	2i	$H_2N^+ + O_2 \leftrightharpoons H_2NO^+ + O$	1.19e-10	0.00	0	531
2050	2i	$H_2N^+ + O_2 \leftrightharpoons HNO^+ + HO$	2.10e-11	0.00	0	531

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2051	2i	$H_2NO_3^+ + H_3N \leftrightharpoons H_4N^+ + HNO_3$	6.40e-10	0.00	0	114
2051 2052	2i	$H_2NO_3^+ + NO \rightleftharpoons H_2NO_2^+ + NO_2$	3.10e-11	0.00	0	114
2052 2053	2i	$H_2NO_3 + NO \rightarrow H_2NO_2 + NO_2$ $H_2O^+ + HCN \rightleftharpoons CH_2N^+ + HO$	2.10e-11 2.10e-09	0.00	0	456
2053 2054	2i	$H_2O^+ + HCN \Rightarrow CH_2N^- + HO$ $H_2O^+ + HCN \Leftrightarrow H_3O^+ + CN$	2.10e-09 2.10e-09	0.00	0	456
2054 2055	2i	$H_2O^+ + CH_4 \rightleftharpoons CH_4^+ + H_2O$	1.20e-09	0.00	0	551
2056	2i	$H_2O^+ + CH_4 \Rightarrow CH_4 + H_2O^+$ $H_2O^+ + CH_4 \Rightarrow H_3O^+ + CH_3$	1.20e-09 1.20e-09	0.00	0	551
2050 2057	2i	$H_2O^+ + CH_4 \rightarrow H_3O^+ + CH_3$ $H_2O^+ + CO \rightleftharpoons CHO^+ + HO$	5.30e-10	0.00	0	492
2058	2i	$H_2O^+ + C_2H_2 \leftrightharpoons C_2H_2^+ + H_2O$	1.90e-09	0.00	0	504
2059	2i	$H_2O^+ + C_2H_2 \rightarrow C_2H_2 + H_2O$ $H_2O^+ + C_2H_4 \rightleftharpoons C_2H_4^+ + H_2O$	1.60e-09	0.00	0	551
2060	2i	$H_2O^+ + C_2H_4 \Rightarrow C_2H_4 + H_2O^+$ $H_2O^+ + C_2H_4 \Leftrightarrow C_2H_5^+ + HO$	1.60e-09	0.00	0	551
2061	2i	$H_2O^+ + C_2H_4 \Rightarrow C_2H_5 + H_0$ $H_2O^+ + C_2H_6 \Leftrightarrow H_3O^+ + C_2H_5$	1.33e-09	0.00	0	467
2062	2i	$H_2O^+ + C_2H_6 \Rightarrow H_3O^- + C_2H_5$ $H_2O^+ + C_2H_6 \Leftrightarrow C_2H_4^+ + H_2O^- + H_2$	1.92e-10	0.00	0	467
2063	2i	$H_2O^+ + C_2H_6 = C_2H_4 + H_2O + H_2$ $H_2O^+ + C_2H_6 = C_2H_6^+ + H_2O$	6.40e-11	0.00	0	467
2064	2i	$H_2O^+ + C_2H_6 \Rightarrow C_2H_6 + H_2O$ $H_2O^+ + C_2H_6 \Leftrightarrow C_2H_5^+ + H_2O + H$	1.60e-11	0.00	0	467
2065	2i	$H_2O^+ + C_2H_6 \rightarrow C_2H_5 + H_2O + H$ $H_2O^+ + NCCN \rightleftharpoons C_2HN_2^+ + HO$	1.00e-11 1.00e-09	0.00	0	469
2066	2i	$H_2O^+ + H_2 \rightleftharpoons H_3O^+ + H$	1.40e-09	0.00	0	110
2067	2i	$H_2O^+ + H_2 = H_3O^+ + H$ $H_2O^+ + H_2O = H_3O^+ + HO$	1.40e-09 1.80e-09	0.00	0	538
2068	2i	$H_2O^+ + N \rightleftharpoons HNO^+ + H$	1.90e-09	0.00	0	453
2069	2i	$H_2O^+ + N \Rightarrow HNO^- + H$ $H_2O^+ + N \Leftrightarrow NO^+ + H_2$	1.90e-10 1.90e-10	0.00	0	453
2070	2i	$H_2O^+ + NO = NO^+ + H_2O$	3.60e-10	0.00	0	552
2071	2i	$H_2O^+ + NO \Rightarrow NO^+ + H_2O$ $H_2O^+ + NO_2 \Leftrightarrow NO_2^+ + H_2O$	1.20e-09	0.00	0	551
2072	2i	$H_2O^+ + N_2O \rightleftharpoons HN_2O^+ + HO$	4.80e-12	0.00	0	553
2073	2i	$H_2O^+ + O \rightleftharpoons O_2^+ + H_2$	3.99e-11	0.00	0	453
2073	2i	$H_2O^+ + O_2 = O_2^+ + H_2O^+$	2.00e-10	0.00	0	110
2074	2i	$H_2O_+^+ + CO = CHO_+^+ + HO_2$	5.50e-10	0.00	0	554
2076	2i	$H_2O_2^+ + H_2O = H_3O^+ + H_2O_2$	1.70e-09	0.00	0	554
2077	2i	$H_2O_2^+ + H_2O_2 \Rightarrow H_3O_2^+ + HO_2$ $H_2O_2^+ + H_2O_2 \Rightarrow H_3O_2^+ + HO_2$	6.00e-10	0.00	0	554
2078	2i	$H_2O_2^+ + H_2O_2 \rightarrow H_3O_2 + H_2O_2$ $H_2O_2^+ + H_3N \rightleftharpoons H_4N^+ + HO_2$	1.80e-09	0.00	0	554
2079	2i	$H_2O_2^+ + H_3N \rightarrow H_4N^+ + HO_2$ $H_2O_2^+ + NO \rightleftharpoons NO^+ + H_2O_2$	5.00e-09	0.00	0	554
2019	2i	$SiH_2^+ + SiH_4 \leftrightharpoons Si_2H_2^+ + H_2 + H_2$	6.98e-11	0.00	0	542
2080	2i	$SiH_2^+ + SiH_4 \rightarrow Si_2H_2^- + H_2^- + H_2^-$ $SiH_2^+ + SiH_4 \Rightarrow Si_2H^+ + H_2 + H_2^- + H_2^-$	1.26e-11	0.00	0	542
2081	2i	$SiH_2^+ + SiH_4 \Rightarrow Si_2H^- + H_2^- + H_1^-$ $SiH_2^+ + SiH_4 \Leftrightarrow Si_2H_3^+ + H_2^- + H_1^-$	1.26e-11 1.16e-11	0.00	0	542
2082	2i	$SiH_2^+ + SiH_4 \rightarrow Si_2H_3^- + H_2^- + H_1^-$ $SiH_2^+ + SiH_4 \rightleftharpoons Si_2^+ + H_2^- + H_2^- + H_2^-$	2.91e-12	0.00		542
2083	2i	$SiH_2 + SiH_4 = Si_2 + H_2 + H_2 + H_2$ $SiH_2^+ + Si_2H_6 = Si_2H_5^+ + SiH_3$	3.70e-10	0.00	0	542 543
	2i	$SiH_{2}^{+} + Si_{2}H_{6} = Si_{2}H_{5}^{-} + SiH_{3}$ $SiH_{2}^{+} + Si_{2}H_{6} = Si_{2}H_{4}^{+} + SiH_{4}$		0.00		
2085	21 2i	$SiH_{2}^{+} + Si_{2}H_{6} = Si_{2}H_{4}^{+} + SiH_{4}^{+}$ $SiH_{2}^{+} + Si_{2}H_{6} = Si_{3}H_{6}^{+} + H_{2}^{-}$	3.15e-10		$0 \\ 0$	543 543
2086	21 2i	$SiH_{2}^{+} + Si_{2}H_{6} = Si_{3}H_{6}^{+} + H_{2}$ $SiH_{2}^{+} + Si_{2}H_{6} = Si_{3}H_{7}^{+} + H$	2.33e-10 2.33e-10	0.00		543 543
2087	2i	$SiH_{2}^{+} + Si_{2}H_{6} = Si_{3}H_{7}^{-} + H$ $SiH_{2}^{+} + Si_{2}H_{6} = Si_{2}H_{2}^{+} + SiH_{4} + H_{2}$		0.00	0	543 543
2088	21 2i	$Sin_2 + Si_2n_6 = Si_2n_2 + Sin_4 + n_2$ $Si_2H_2^+ + Si_2H_6 = Si_4H_4^+ + H_2 + H_2$	1.37e-10	0.00	0	543 543
2089			2.26e-10	0.00	0	543
2090	2i	$Si_2H_2^+ + Si_2H_6 \leftrightharpoons Si_3H_4^+ + SiH_4$	1.11e-10	0.00	0	543
2091	2i	$\operatorname{Si}_{2}\operatorname{H}_{2}^{+} + \operatorname{Si}_{2}\operatorname{H}_{6} \leftrightharpoons \operatorname{Si}_{4}\operatorname{H}_{6}^{+} + \operatorname{H}_{2}$	7.38e-11	0.00	0	543

Table 6—Continued

$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	TABLE 0—Commuea								
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	#	Type	Reaction	α	β	γ	Ref		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2092	2i	$H_3^+ + Ar \leftrightharpoons ArH^+ + H_2$	9.99e-12	0.00	0	433		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2093	2i	$H_3^+ + HCN \leftrightharpoons CH_2N^+ + H_2$	7.00e-09	0.00	0	555		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2094	2i	$H_3^+ + CH_2O \leftrightharpoons CH_3O^+ + H_2$	6.30e-09	0.00	0	490		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2095	2i	$H_3^+ + HCOOH = CHO^+ + H_2O + H_2$	4.27e-09	0.00	0	491		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2096	2i	$H_3^+ + HCOOH \leftrightharpoons H_3O^+ + CO + H_2$	1.83e-09	0.00	0	491		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2097	2i	$H_3^+ + CH_3NO_2 \leftrightharpoons CH_4NO_2^+ + H_2$	4.42e-09	0.00	0	462		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2098	2i	$H_3^+ + CH_3NO_2 \leftrightharpoons NO^+ + CH_3OH + H_2$	3.53e-09	0.00	0	462		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2099	2i	$H_3^+ + CH_3NO_2 \leftrightharpoons CH_3NO_2^+ + H_2 + H$	8.03e-11	0.00	0	462		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2100	2i	$H_3^+ + CH_4 \leftrightharpoons CH_5^+ + H_2$	1.60e-09	0.00	0	111		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2101	2i	$H_3^+ + CO = CHO^+ + H_2$	1.40e-09	0.00	0	111		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2102	2i	$H_3^+ + CO_2 \leftrightharpoons CHO_2^+ + H_2$	1.90e-09	0.00	0	111		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2103	2i	$H_3^+ + C_2H_2 \leftrightharpoons C_2H_3^+ + H_2$	2.90e-09	0.00	0	464		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2104	2i	$H_3^+ + CH_3CN \leftrightharpoons C_2H_4N^+ + H_2$	7.30e-09	0.00	0	555		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2105	2i	$H_3^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + H_2$	1.90e-09	0.00	0	111		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2106	2i		1.21e-09	0.00	0	111		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2107	2i		6.80e-09	0.00	0	491		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2108	2i		7.30e-09	0.00	0	495		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2109	2i		7.30e-09	0.00	0	495		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2110	2i	$H_3^+ + C_2H_6 \leftrightharpoons C_2H_7^+ + H_2$		0.00	0	111		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2111			2.40e-09		0			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2112					0	555		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2113	2i		1.05e-08	0.00	0	469		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2114	2i				0			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2115					0			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2116			1.40e-09		0			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2117					0			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2118								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2119								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2120								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2121								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2122								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2123								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2124	2i				0	485		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2125			9.00e-10					
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2126		$H_3N^+ + CH_5N \leftrightharpoons CH_5N^+ + H_3N$						
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2127								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2128	2i	$H_3N^+ + CH_5N \leftrightharpoons H_4N^+ + CH_3 + HN$	2.70e-10	0.00	0	531		
2130 2i $H_3N^+ + C_2H_4O = H_4N^+ + C_2H_3O$ 4.37e-10 0.00 0 470 2131 2i $H_3N^+ + (CH_3)_2O = H_4N^+ + CH_3CH_2O$ 9.37e-10 0.00 0 470	2129	2i	$H_3N^+ + C_2H_4 \leftrightharpoons H_4N^+ + C_2H_3$	1.40e-09	0.00	0	532		
2131 2i $H_3N^+ + (CH_3)_2O = H_4N^+ + CH_3CH_2O$ 9.37e-10 0.00 0 470	2130	2i		4.37e-10	0.00	0	470		
	2131	2i		9.37e-10	0.00	0	470		
	2132	2i	$H_3N^+ + H_2 \leftrightharpoons H_4N^+ + H$	4.89e-12	0.00	510			

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2133	2i	$H_3N^+ + H_2O \leftrightharpoons H_4N^+ + HO$	1.63e-10	0.00	0	558
2134	2i	$H_3N^+ + H_2O \leftrightharpoons H_3O^+ + H_2N$	8.75e-11	0.00	0	558
2135	2i	$H_3N^+ + H_3N \leftrightharpoons H_4N^+ + H_2N$	1.07e-09	0.00	0	538
2136	2i	$H_3N^+ + NO \leftrightharpoons NO^+ + H_3N$	7.20e-10	0.00	0	531
2137	2i	$H_3O^+ + HCN \leftrightharpoons CH_2N^+ + H_2O$	3.50e-09	0.00	0	465
2138	2i	$H_3O^+ + CH_2O \leftrightharpoons CH_3O^+ + H_2O$	3.00e-09	0.00	0	463
2139	2i	$H_3O^+ + HCOOH \leftrightharpoons CH_3O_2^+ + H_2O$	2.70e-09	0.00	0	491
2140	2i	$\mathrm{H_3O^+} + \mathrm{CH_3NO_2} \leftrightharpoons \mathrm{CH_4NO_2^+} + \mathrm{H_2O}$	4.11e-09	0.00	0	462
2141	2i	$H_3O^+ + CH_3OH \leftrightharpoons CH_5O^+ + H_2O$	2.20e-09	0.00	0	559
2142	2i	$H_3O^+ + C_2H_2O \leftrightharpoons C_2H_3O^+ + H_2O$	2.00e-09	0.00	0	560
2143	2i	$H_3O^+ + CH_3CN \leftrightharpoons C_2H_4N^+ + H_2O$	4.70e-09	0.00	0	465
2144	2i	$H_3O^+ + C_2H_4 \leftrightharpoons C_2H_5^+ + H_2O$	6.30e-11	0.00	0	561
2145	2i	$H_3O^+ + C_2H_4O \leftrightharpoons C_2H_5O^+ + H_2O$	3.60e-09	0.00	0	560
2146	2i	$H_3O^+ + CH_3COOH \rightleftharpoons C_2H_5O_2^+ + H_2O$	2.85e-09	0.00	0	491
2147	2i	$H_3O^+ + CH_3COOH \rightleftharpoons C_2H_3O^+ + H_2O + H_2O$	1.50e-10	0.00	0	491
2148	2i	$H_3O^+ + CH_3OCHO \rightleftharpoons C_2H_5O_2^+ + H_2O$	3.00e-09	0.00	0	562
2149	2i	$H_3O^+ + (CH_3)_2O = C_2H_7O^+ + H_2O$	2.70e-09	0.00	0	560
2150	2i	$H_3O^+ + C_2H_5OH \rightleftharpoons C_2H_7O^+ + H_2O$	2.80e-09	0.00	0	560
2151	2i	$H_3O^+ + HC_3N \leftrightharpoons C_3H_2N^+ + H_2O$	3.80e-09	0.00	0	469
2152	2i	$H_3O^+ + HNO_3 \rightleftharpoons H_2NO_3^+ + H_2O$	1.60e-09	0.00	0	114
2153	2i	$H_3O^+ + H_3N \leftrightharpoons H_4N^+ + H_2O$	2.50e-09	0.00	0	563
2154	2i	$H_3O^+ + NO = NO^+ + H_2O + H$	1.50e-12	0.00	0	564
2155	2i	$H_3O_2^+ + H_2O = H_3O^+ + H_2O_2$	1.00e-10	0.00	0	554
2156	2i	$H_3O_2^+ + O_2 \leftrightharpoons HO_4^+ + H_2$	5.00e-10	0.00	0	111
2157	2i	$SiH_3^+ + H_2O \leftrightharpoons SiH_3O^+ + H_2$	5.80e-12	0.00	0	565
2158	2i	$SiH_3^+ + SiH_4 = Si_2H^+ + H_2 + H_2 + H_2$	1.30e-10	0.00	0	542
2159	2i	$SiH_3^+ + SiH_4 \leftrightharpoons Si_2H_3^+ + H_2 + H_2$	1.20e-10	0.00	0	542
2160	2i	$SiH_3^+ + SiH_4 \leftrightharpoons Si_2H_2^+ + H_2 + H_2 + H$	2.50e-11	0.00	0	542
2161	2i	$SiH_3^+ + Si_2H_6 \leftrightharpoons Si_2H_5^+ + SiH_4$	5.22e-10	0.00	0	543
2162	2i	$\operatorname{SiH}_{3}^{+} + \operatorname{Si}_{2}\operatorname{H}_{6} \leftrightharpoons \operatorname{Si}_{3}\operatorname{H}_{7}^{+} + \operatorname{H}_{2}$	3.48e-10	0.00	0	543
2163	2i	$\mathrm{Si}_{2}\mathrm{H}_{3}^{+} + \mathrm{Si}_{2}\mathrm{H}_{6} \leftrightharpoons \mathrm{Si}_{4}\mathrm{H}_{5}^{+} + \mathrm{H}_{2} + \mathrm{H}_{2}$	3.13e-10	0.00	0	543
2164	2i	$\operatorname{Si}_{2}\operatorname{H}_{3}^{+} + \operatorname{Si}_{2}\operatorname{H}_{6} \leftrightharpoons \operatorname{Si}_{3}\operatorname{H}_{5}^{+} + \operatorname{Si}\operatorname{H}_{4}$	1.20e-10	0.00	0	543
2165	2i	$\operatorname{Si}_{2}\operatorname{H}_{3}^{+} + \operatorname{Si}_{2}\operatorname{H}_{6} \leftrightharpoons \operatorname{Si}_{3}\operatorname{H}_{3}^{+} + \operatorname{SiH}_{4} + \operatorname{H}_{2}$	6.77e-11	0.00	0	543
2166	2i	$\operatorname{Si}_{2}\operatorname{H}_{3}^{+} + \operatorname{Si}_{2}\operatorname{H}_{6} \leftrightharpoons \operatorname{Si}_{4}\operatorname{H}_{7}^{+} + \operatorname{H}_{2}$	2.08e-11	0.00	0	543
2167	2i	$H_4N^+ + CH_5N \leftrightharpoons CH_6N^+ + H_3N$	2.00e-09	0.00	0	566
2168	2i	$Fe^+ + N_2O \leftrightharpoons FeO^+ + N_2$	7.00e-11	0.00	0	567
2169	2i	$Fe^+ + O_3 \leftrightharpoons FeO^+ + O_2$	1.50e-10	0.00	0	108
2170	2i	$FeO^+ + CO \leftrightharpoons Fe^+ + CO_2$	9.00e-10	0.00	0	567
2171	2i	$He^+ + Ar \leftrightharpoons Ar^+ + He$	5.00e-14	0.00	0	568
2172	2i	$He^+ + HCN \leftrightharpoons CN^+ + H + He$	1.95e-09	0.00	0	457
2173	2i	$He^+ + HCN \leftrightharpoons CHN^+ + He$	7.80e-10	0.00	0	457

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2174	2i	$He^+ + HCN \leftrightharpoons CH^+ + He + N$	7.80e-10	0.00	0	457
2175	2i	$He^+ + HCN = C^+ + H + He + N$	3.90e-10	0.00	0	457
2176	2i	$He^+ + HCOOH = CHO^+ + HO + He$	2.87e-09	0.00	0	443
2177	2i	$He^+ + HCOOH = CHO_2^+ + H + He$	1.23e-09	0.00	0	443
2178	2i	$He^+ + HCOOH = CH_2O_2^+ + He$	4.10e-10	0.00	0	443
2179	2i	$He^+ + CH_4 \leftrightharpoons CH_2^+ + H_2^- + He$	9.12e-10	0.00	0	569
2180	2i	$He^+ + CH_4 \leftrightharpoons H^+ + CH_3 + He$	3.04e-10	0.00	0	569
2181	2i	$He^+ + CH_4 \leftrightharpoons CH^+ + H_2 + H + He$	2.72e-10	0.00	0	569
2182	2i	$He^+ + CH_4 \leftrightharpoons CH_3^+ + H + He$	9.60e-11	0.00	0	569
2183	2i	$He^+ + CH_4 \leftrightharpoons CH_4^+ + He$	1.60e-11	0.00	0	569
2184	2i	$He^+ + CO \leftrightharpoons CO^+ + He$	1.60e-09	0.00	0	423
2185	2i	$He^+ + CO \leftrightharpoons C^+ + O + He$	1.05e-09	0.00	0	422
2186	2i	$He^+ + CO \leftrightharpoons O^+ + C + He$	3.50e-10	0.00	0	422
2187	2i	$He^+ + CO_2 \leftrightharpoons CO^+ + O + He$	8.69e-10	0.00	0	569
2188	2i	$He^+ + CO_2 \leftrightharpoons CO_2^+ + He$	1.21e-10	0.00	0	569
2189	2i	$He^+ + CO_2 \leftrightharpoons O^+ + CO + He$	9.90e-11	0.00	0	569
2190	2i	$He^+ + CO_2 \leftrightharpoons O_2^+ + C + He$	1.10e-11	0.00	0	569
2191	2i	$\mathrm{He^+} + \mathrm{C_2H_6} \leftrightharpoons \mathrm{C_2H_6^+} + \mathrm{He}$	2.66e-09	0.00	0	425
2192	2i	$\mathrm{He^+} + \mathrm{C_2H_6} \leftrightharpoons \mathrm{C_2H_5^+} + \mathrm{H} + \mathrm{He}$	2.66e-09	0.00	0	425
2193	2i	$\mathrm{He^+} + \mathrm{C_2H_6} \leftrightharpoons \mathrm{H^+} + \mathrm{C_2H_5} + \mathrm{He}$	2.66e-09	0.00	0	425
2194	2i	$He^{+} + C_{2}H_{6} \leftrightharpoons C_{2}H_{4}^{+} + H_{2} + He$	2.66e-09	0.00	0	425
2195	2i	$He^+ + C_2H_6 \leftrightharpoons C_2H_3^+ + H_2 + H + He$	2.66e-09	0.00	0	425
2196	2i	$He^+ + HC_3N \leftrightharpoons C_2^+ + HCN + He$	2.30e-09	0.00	0	479
2197	2i	$He^+ + HC_3N \leftrightharpoons C_3^+ + HN + He$	2.30e-09	0.00	0	479
2198	2i	$He^+ + HC_3N \leftrightharpoons C_2H^+ + CN + He$	2.30e-09	0.00	0	479
2199	2i	$\mathrm{He^+} + \mathrm{H_2} \leftrightharpoons \mathrm{HeH^+} + \mathrm{H}$	5.00e-13	0.00	0	547
2200	2i	$\mathrm{He^+} + \mathrm{H_2} \leftrightharpoons \mathrm{H_2^+} + \mathrm{He}$	5.00e-13	0.00	0	547
2201	2i	$He^+ + H_2 \leftrightharpoons H^+ + H + He$	2.00e-12	0.00	0	547
2202	2i	$He^+ + H_2O \leftrightharpoons HeH^+ + HO$	1.00e-10	0.00	0	570
2203	2i	$He^+ + H_2O \leftrightharpoons HO^+ + H + He$	4.57e-10	0.00	0	570
2204	2i	$He^+ + H_2O \leftrightharpoons H_2O^+ + He$	9.35e-11	0.00	0	570
2205	2i	$He^+ + H_3N \leftrightharpoons H_2N^+ + H + He$	1.60e-09	0.00	0	428
2206	2i	$He^+ + H_3N \leftrightharpoons H_3N^+ + He$	2.40e-10	0.00	0	428
2207	2i	$He^+ + H_3N \leftrightharpoons HN^+ + H_2 + He$	1.60e-10	0.00	0	428
2208	2i	$He^+ + SiH_4 \leftrightharpoons Si^+ + H_2 + H_2 + He$	2.40e-09	0.00	0	425
2209	2i	$He^+ + SiH_4 \leftrightharpoons SiH^+ + H_2 + H + He$	2.40e-09	0.00	0	425
2210	2i	$He^+ + SiH_4 \rightleftharpoons H^+ + SiH_3 + He$	2.40e-09	0.00	0	425
2211	2i	$He^{+} + Si_{2}H_{6} \leftrightharpoons Si_{2}H_{2}^{+} + H_{2} + H_{2} + He$	2.40e-09	0.00	0	425
2212	2i	$He^+ + NO = NO^+ + He$	1.60e-09	0.00	0	423
2213	2i	$He^+ + NO \leftrightharpoons N^+ + O + He$	9.38e-10	0.00	0	422
2214	2i	$He^+ + NO \leftrightharpoons O^+ + N + He$	3.13e-10	0.00	0	422

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2215	2i	$He^+ + N_2 \leftrightharpoons N^+ + N + He$	8.25e-10	0.00	0	571
2216	2i	$He^+ + N_2 \leftrightharpoons N_2^+ + He$	6.75 e-10	0.00	0	571
2217	2i	$He^+ + N_2O = N_2O^+ + He$	2.30e-09	0.00	0	423
2218	2i	$He^+ + O_2 \leftrightharpoons O^+ + O + He$	6.80 e-10	0.00	0	571
2219	2i	$He^+ + O_2 \leftrightharpoons O_2^+ + He$	1.70e-10	0.00	0	571
2220	2i	$HeH^{+} + C_{2}H_{6} = C_{2}H_{5}^{+} + H_{2} + He$	2.10e-09	0.00	0	467
2221	2i	$HeH^+ + C_2H_6 \leftrightharpoons C_2H_3^+ + H_2 + H_2 + H_2$	2.10e-09	0.00	0	467
2222	2i	$HeH^+ + H_2 \leftrightharpoons H_3^+ + He$	1.50e-09	0.00	0	572
2223	2i	$HeH^+ + N_2 \leftrightharpoons HN_2^+ + He$	1.70e-09	0.00	0	556
2224	2i	$HeH^+ + O_2 \leftrightharpoons HO_2^+ + He$	1.10e-09	0.00	0	492
2225	2i	$He_2^+ + Ar \leftrightharpoons Ar^+ + He + He$	2.00e-10	0.00	0	437
2226	2i	$He_2^+ + CO = CO^+ + He + He$	1.40e-09	0.00	0	437
2227	2i	$\operatorname{He}_{2}^{+} + \operatorname{CO}_{2} \leftrightharpoons \operatorname{CO}^{+} + \operatorname{O} + \operatorname{He} + \operatorname{He}$	1.80e-09	0.00	0	437
2228	2i	$\operatorname{He}_{2}^{+} + \operatorname{CO}_{2} \leftrightharpoons \operatorname{CO}_{2}^{+} + \operatorname{He} + \operatorname{He}$	1.80e-09	0.00	0	437
2229	2i	$\operatorname{He}_{2}^{+} + \operatorname{CO}_{2} \leftrightharpoons \operatorname{O}^{+} + \operatorname{CO} + \operatorname{He} + \operatorname{He}$	1.80e-09	0.00	0	437
2230	2i	$\text{He}_2^+ + \text{NO} \leftrightharpoons \text{NO}^+ + \text{He} + \text{He}$	1.30e-09	0.00	0	437
2231	2i	$\operatorname{He}_{2}^{+} + \operatorname{N}_{2} \leftrightharpoons \operatorname{N}_{2}^{+} + \operatorname{He} + \operatorname{He}$	1.20e-09	0.00	0	437
2232	2i	$He_2^+ + O_2 \leftrightharpoons O_2^+ + He + He$	7.88e-10	0.00	0	437
2233	2i	$\operatorname{He}_{2}^{+} + \operatorname{O}_{2} = \operatorname{O}^{+} + \operatorname{O} + \operatorname{He} + \operatorname{He}$	2.63e-10	0.00	0	437
2234	2i	$He_2^+ + O_2 \leftrightharpoons O^+ + O + He + He$	2.63e-10	0.00	0	437
2235	2i	$Mg^+ + HNO_3 \leftrightharpoons MgHO^+ + NO_2$	5.80e-11	0.00	0	573
2236	2i	$Mg^+ + H_2O_2 \leftrightharpoons MgHO^+ + HO$	1.30e-09	0.00	0	573
2237	2i	$Mg^+ + N_2O \leftrightharpoons MgO^+ + N_2$	7.00e-10	0.00	0	573
2238	2i	$Mg^+ + O_3 \leftrightharpoons MgO^+ + O_2$	2.30e-10	0.00	0	108
2239	2i	$MgO^+ + CO \leftrightharpoons Mg^+ + CO_2$	3.20e-10	0.00	0	573
2240	2i	$MgO^+ + NO \leftrightharpoons Mg^+ + NO_2$	4.30e-10	0.00	0	573
2241	2i	$MgO^+ + O \leftrightharpoons Mg^+ + O_2$	1.00e-10	0.00	0	108
2242	2i	$MgO^+ + O_3 \leftrightharpoons Mg^+ + O_2 + O_2$	8.00e-10	0.00	0	573
2243	2i	$MgHO^+ + HNO_3 \leftrightharpoons NO_2^+ + MgO_2H_2$	4.40e-10	0.00	0	573
2244	2i	$MgHO^+ + H_2O_2 \leftrightharpoons MgH_2O_2^+ + HO$	1.00e-09	0.00	0	573
2245	2i	$N^+ + CH_2O \rightleftharpoons CH_2O^+ + N$	1.89e-09	0.00	0	574
2246	2i	$N^+ + CH_2O \leftrightharpoons CHO^+ + HN$	7.25e-10	0.00	0	574
2247	2i	$N^+ + CH_2O \leftrightharpoons NO^+ + CH_2$	2.90e-10	0.00	0	574
2248	2i	$N^+ + HCOOH = CHO^+ + HNO$	6.20e-09	0.00	0	443
2249	2i	$N^+ + CH_4 \leftrightharpoons CH_3^+ + HN$	4.79e-10	0.00	0	574
2250	2i	$N^+ + CH_4 \leftrightharpoons CH_2N^+ + H_2$	3.76e-10	0.00	0	574
2251	2i	$N^+ + CH_4 \leftrightharpoons CHN^+ + H_2 + H$	5.64e-11	0.00	0	574
2252	2i	$N^+ + CH_4 \leftrightharpoons CH_4^+ + N$	2.82e-11	0.00	0	574
2253	2i	$N^+ + CH_3OH \leftrightharpoons CH_4O^+ + N$	1.40e-09	0.00	0	574
2254	2i	$N^+ + CH_3OH \rightleftharpoons CH_2O^+ + H_2N$	6.00e-10	0.00	0	574
2255	2i	$N^+ + CH_3OH \rightleftharpoons CH_3O^+ + HN$	3.20e-10	0.00	0	574

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2256	2i	$N^+ + CH_3OH \leftrightharpoons NO^+ + CH_4$	2.00e-10	0.00	0	574
2257	2i	$N^+ + CH_3OH \leftrightharpoons CH_3^+ + HNO$	8.00e-11	0.00	0	574
2258	2i	$N^+ + CH_5N \leftrightharpoons CH_4N^+ + HN$	1.40e-09	0.00	0	574
2259	2i	$N^+ + CH_5N \leftrightharpoons CH_2N^+ + HN + H_2$	2.00e-10	0.00	0	574
2260	2i	$N^+ + CH_5N \leftrightharpoons CH_3N^+ + H_2N$	1.40e-10	0.00	0	574
2261	2i	$N^+ + CH_5N \leftrightharpoons CH_5N^+ + N$	1.40e-10	0.00	0	574
2262	2i	$N^+ + CH_5N \leftrightharpoons CH_3^+ + H_2 + N_2$	1.20e-10	0.00	0	574
2263	2i	$N^+ + CO = CO^+ + N$	3.96e-10	0.00	0	574
2264	2i	$N^+ + CO = NO^+ + C$	5.40e-11	0.00	0	574
2265	2i	$N^+ + CO_2 \leftrightharpoons CO_2^+ + N$	7.50e-10	0.00	0	574
2266	2i	$N^+ + CO_2 = CO^+ + NO$	2.50e-10	0.00	0	574
2267	2i	$N^+ + C_2H_4 \leftrightharpoons C_2H_3^+ + HN$	4.80e-10	0.00	0	532
2268	2i	$N^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + N$	4.00e-10	0.00	0	532
2269	2i	$N^+ + C_2H_4 \leftrightharpoons CHN^+ + CH_3$	2.40e-10	0.00	0	532
2270	2i	$N^+ + C_2H_4 \leftrightharpoons C_2H_2^+ + H_2N$	1.60e-10	0.00	0	532
2271	2i	$N^+ + C_2H_4 \leftrightharpoons CH_2N^+ + CH_2$	1.60e-10	0.00	0	532
2272	2i	$N^+ + C_2H_4 \leftrightharpoons C_2H_2N^+ + H_2$	1.60e-10	0.00	0	532
2273	2i	$N^+ + NCCN \rightleftharpoons C_2N^+ + N_2$	9.80e-10	0.00	0	446
2274	2i	$N^+ + NCCN \leftrightharpoons C_2N_2^+ + N$	4.20e-10	0.00	0	446
2275	2i	$N^+ + H_2 \leftrightharpoons HN^+ + H$	4.80e-10	0.00	0	574
2276	2i	$N^+ + H_2O \rightleftharpoons H_2O^+ + N$	2.80e-09	0.00	0	574
2277	2i	$N^+ + H_3N \leftrightharpoons H_3N^+ + N$	1.97e-09	0.00	0	574
2278	2i	$N^+ + H_3N \leftrightharpoons HN_2^+ + H_2$	2.16e-10	0.00	0	574
2279	2i	$N^+ + H_3N \leftrightharpoons H_2N^+ + HN$	2.16e-10	0.00	0	574
2280	2i	$N^+ + NO = NO^+ + N$	4.51e-10	0.00	0	575
2281	2i	$N^+ + NO = N_2^+ + O$	7.95e-11	0.00	0	575
2282	2i	$N^+ + O_2 = O_2^+ + N$	3.11e-10	0.00	0	574
2283	2i	$N^+ + O_2 = NO^+ + O$	2.62e-10	0.00	0	574
2284	2i	$N^+ + O_2 \leftrightharpoons O^+ + NO$	3.66e-11	0.00	0	574
2285	2i	$NO^+ + CH_5N \leftrightharpoons CH_5N^+ + NO$	8.20e-10	0.00	0	574
2286	2i	$NO^+ + C_2H_4O \rightleftharpoons C_2H_3O^+ + HNO$	3.50e-10	0.00	0	576
2287	2i	$NO^+ + C_2H_5OH \rightleftharpoons C_2H_5O^+ + HNO$	8.00e-10	0.00	0	576
2288	2i	$NO_2^+ + C_2H_6 \rightleftharpoons C_2H_5^+ + NO + HO$	8.90e-10	0.00	0	528
2289	2i	$NO_2^+ + N \leftrightharpoons NO^+ + NO$	7.99e-12	0.00	0	577
2290	2i	$NO_2^+ + NO \leftrightharpoons NO^+ + NO_2$	2.90e-10		0	578
2291	2i	$NO_2^+ + O = NO^+ + O_2$	7.99e-12	0.00	0	577
2292	2i	$N_2^+ + Ar \leftrightharpoons Ar^+ + N_2$	3.50e-11	0.00	0	431
2293	2i	$N_2^+ + CH_2O \rightleftharpoons CHO^+ + N_2 + H$	2.52e-09	0.00	0	574
2294	2i	$N_2^+ + CH_2O \rightleftharpoons CH_2O^+ + N_2$	3.77e-10	0.00	0	574
2295	2i	$N_2^+ + HCOOH \rightleftharpoons CHO^+ + N_2 + HO$	4.60e-09	0.00	0	443
2296	2i	$N_2^+ + CH_4 \leftrightharpoons CH_3^+ + N_2 + H$	9.30e-10	0.00	0	574

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2297	2i	$N_2^+ + CH_4 \leftrightharpoons CH_2^+ + N_2 + H_2$	7.00e-11	0.00	0	574
2298	2i	$N_2^+ + CH_3OH = CH_3^+ + HO + N_2$	1.11e-09	0.00	0	574
2299	2i	$N_2^+ + CH_3OH \leftrightharpoons CH_3O^+ + N_2 + H$	1.68e-10	0.00	0	574
2300	2i	$N_2^+ + CH_3OH = CH_4O^+ + N_2$	1.26e-10	0.00	0	574
2301	2i	$N_2^{+} + CH_5N \leftrightharpoons CH_4N^+ + N_2 + H$	8.76e-10	0.00	0	574
2302	2i	$N_2^{+} + CH_5N \leftrightharpoons CH_3^{+} + H_2N + N_2$	2.52e-10	0.00	0	574
2303	2i	$N_2^+ + CH_5N \leftrightharpoons CH_5N^+ + N_2$	7.20e-11	0.00	0	574
2304	2i	$N_2^+ + CO = CO^+ + N_2$	7.40e-11	0.00	0	574
2305	2i	$N_2^+ + CO_2 \leftrightharpoons CO_2^+ + N_2$	7.70e-10	0.00	0	574
2306	2i	$N_2^+ + NCCN \leftrightharpoons \overline{C_2}N_2^+ + N_2$	8.17e-10	0.00	0	436
2307	2i	$N_2^+ + NCCN \leftrightharpoons N_3^+ + C_2N$	2.15e-11	0.00	0	Est
2308	2i	$N_2^+ + NCCN \leftrightharpoons CN_2^+ + CN_2$	2.15e-11	0.00	0	Est
2309	2i	$N_2^+ + HC_3N \leftrightharpoons C_3HN^+ + N_2$	4.10e-09	0.00	0	479
2310	2i	$N_2^+ + H_2 \leftrightharpoons HN_2^+ + H$	1.41e-09	0.00	0	574
2311	2i	$N_2^+ + H_2O \leftrightharpoons HN_2^+ + HO$	9.88e-10	0.00	0	535
2312	2i	$N_2^+ + H_2O \leftrightharpoons H_2O^+ + N_2$	9.12e-10	0.00	0	535
2313	2i	$N_2^+ + H_3N \leftrightharpoons H_3N^+ + N_2$	1.90e-09	0.00	0	574
2314	2i	$N_2^{\dagger} + N \leftrightharpoons N^+ + N_2$	9.99e-12	0.00	0	579
2315	2i	$N_2^+ + NO = NO^+ + N_2$	3.30e-10	0.00	0	507
2316	2i	$N_2^{\dagger} + N_2 \leftrightharpoons N_3^+ + N$	2.76e-12	0.00	0	580
2317	2i	$N_2^+ + N_2O \leftrightharpoons N_2O^+ + N_2$	7.00e-10	0.00	0	579
2318	2i	$N_2^+ + O \leftrightharpoons NO^+ + N$	1.34e-10	0.00	0	507
2319	2i	$N_2^+ + O \leftrightharpoons O^+ + N_2$	5.60e-12	0.00	0	507
2320	2i	$N_2^+ + O_2 \leftrightharpoons O_2^+ + N_2$	5.10e-11	0.00	0	581
2321	2i	$N_2O^+ + CH_4 = HN_2O^+ + CH_3$	9.74e-10	0.00	0	582
2322	2i	$N_2O^+ + CH_4 \leftrightharpoons CH_4^+ + N_2O$	1.23e-10	0.00	0	582
2323	2i	$N_2O^+ + CO = NO^+ + NCO$	3.14e-10	0.00	0	582
2324	2i	$N_2O^+ + CO \leftrightharpoons CO_2^+ + N_2$	2.57e-10	0.00	0	582
2325	2i	$N_2O^+ + H_2 \leftrightharpoons HN_2O^+ + H$	2.60e-10	0.00	0	582
2326	2i	$N_2O^+ + H_3N \leftrightharpoons H_3N^+ + N_2O$	1.82e-09	0.00	0	582
2327	2i	$N_2O^+ + NO \leftrightharpoons NO^+ + N_2O$	4.30e-10	0.00	0	582
2328	2i	$N_2O^+ + NO_2 \leftrightharpoons NO^+ + N_2 + O_2$	4.29e-10	0.00	0	583
2329	2i	$N_2O^+ + NO_2 \leftrightharpoons NO_2^+ + N_2O$	2.21e-10	0.00	0	583
2330	2i	$N_2O^+ + N_2O \leftrightharpoons NO^+ + N_2 + NO$	1.20e-11	0.00	0	583
2331	2i	$N_2O^+ + O_2 \leftrightharpoons O_2^+ + N_2O$	3.90e-10	0.00	0	582
2332	2i	$N_3^+ + CH_2O \leftrightharpoons HN_3^+ + CHO$	9.88e-10	0.00	0	574
2333	2i	$N_3^+ + CH_2O \leftrightharpoons CH_2O^+ + N_2 + N$	4.94e-10	0.00	0	574
2334	2i	$N_3^+ + CH_2O \leftrightharpoons CHO^+ + HN + N_2$	3.04e-10	0.00	0	574
2335	2i	$N_3^+ + CH_2O \leftrightharpoons H_2N^+ + CO + N_2$	1.14e-10	0.00	0	574
2336	2i	$N_3^+ + CH_4 \leftrightharpoons CH_2N^+ + H_2 + N_2$	4.56e-11	0.00	0	574
2337	2i	$N_3^+ + CH_4 \leftrightharpoons CH_4N^+ + N_2$	2.40e-12	0.00	0	574

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2338	2i	$N_3^+ + CH_3OH = CH_4O^+ + N_2 + N$	5.00e-10	0.00	0	574
2339	2i	$N_3^+ + CH_3OH \Rightarrow CH_3O^+ + HN + N_2$	2.80e-10	0.00	0	574
2340	2i	$N_3^+ + CH_3OH \Rightarrow NO^+ + CH_4 + N_2$	2.20e-10	0.00	0	574
2341	2i	$N_3^+ + CH_5N \leftrightharpoons CH_4N^+ + HN + N_2$	8.69e-10	0.00	0	574
2342	2i	$N_3^+ + CH_5N \leftrightharpoons CH_5N^+ + N_2 + N$	2.31e-10	0.00	0	574
2343	2i	$N_3^+ + H_2 \leftrightharpoons HN_2^+ + HN$	2.00e-13	0.00	0	574
2344	2i	$N_3^+ + H_2O \leftrightharpoons H_2NO^+ + N_2$	3.30e-10	0.00	0	574
2345	2i	$N_3^+ + H_3N \leftrightharpoons H_3N^+ + N_2 + N$	2.10e-09	0.00	0	574
2346	2i	$N_3^+ + NO \leftrightharpoons NO^+ + N_2 + N$	1.40e-10	0.00	0	584
2347	2i	$N_3^+ + NO \leftrightharpoons N_2O^+ + N_2$	1.40e-10	0.00	0	584
2348	2i	$N_3^+ + O_2 \leftrightharpoons NO^+ + N_2O$	3.57e-11	0.00	0	574
2349	2i	$N_3^+ + O_2 \leftrightharpoons NO_2^+ + N_2$	1.53e-11	0.00	0	574
2350	2i	$O^+ + HCN \leftrightharpoons CO^+ + HN$	3.50e-09	0.00	0	529
2351	2i	$O^+ + HCN \leftrightharpoons CHO^+ + N$	3.50e-09	0.00	0	529
2352	2i	$O^+ + HCN \leftrightharpoons NO^+ + CH$	3.50e-09	0.00	0	529
2353	2i	$O^+ + CH_2O \leftrightharpoons CH_2O^+ + O$	2.10e-09	0.00	0	574
2354	2i	$O^+ + CH_2O \leftrightharpoons CHO^+ + HO$	1.40e-09	0.00	0	574
2355	2i	$O^+ + HCOOH \leftrightharpoons CHO^+ + O_2 + H$	3.50e-09	0.00	0	443
2356	2i	$O^+ + HCOOH = CHO^+ + HO_2$	1.50e-09	0.00	0	443
2357	2i	$O^+ + CH_4 \leftrightharpoons CH_4^+ + O$	8.90e-10	0.00	0	574
2358	2i	$O^+ + CH_4 \leftrightharpoons CH_3^+ + HO$	1.10e-10	0.00	0	574
2359	2i	$O^+ + CH_3OH \leftrightharpoons CH_3O^+ + HO$	1.33e-09	0.00	0	574
2360	2i	$O^+ + CH_3OH \leftrightharpoons CH_4O^+ + O$	4.75e-10	0.00	0	574
2361	2i	$O^+ + CH_3OH \leftrightharpoons CH_2O^+ + H_2O$	9.50e-11	0.00	0	574
2362	2i	$O^+ + CH_5N \leftrightharpoons CH_4N^+ + HO$	1.66e-09	0.00	0	574
2363	2i	$O^+ + CH_5N \leftrightharpoons CH_3N^+ + H_2O$	3.15e-10	0.00	0	574
2364	2i	$O^+ + CH_5N \leftrightharpoons CH_5N^+ + O$	1.26e-10	0.00	0	574
2365	2i	$O^{+}(^{2}D) + CO = CO^{+} + O$	1.30e-09	0.00	0	585
2366	2i	$O^+(^3P) + CO = CO^+ + O$	1.30e-09	0.00	0	585
2367	2i	$O^+ + CO_2 \leftrightharpoons CO_2^+ + O$	9.00e-10	0.00	0	586
2368	2i	$O^+ + CO_2 \leftrightharpoons O_2^+ + CO$	9.00e-10	0.00	0	586
2369	2i	$O^+ + C_2H_6 \leftrightharpoons C_2H_4^+ + H_2O$	1.33e-09	0.00	0	467
2370	2i	$O^+ + C_2H_6 \leftrightharpoons C_2H_5^+ + HO$	5.70e-10	0.00	0	467
2371	2i	$O^+ + H_2 \leftrightharpoons HO^+ + H$	1.70e-09	0.00	0	574
2372	2i	$O^+ + H_2O \rightleftharpoons H_2O^+ + O$	3.20e-09	0.00	0	574
2373	2i	$O^+ + H_3N \leftrightharpoons H_3N^+ + O$	1.20e-09	0.00	0	574
2374	2i	$O^{+}(^{2}D) + NO = NO^{+} + O$	1.20e-09	0.00	0	585
2375	2i	$O^+(^3P) + NO = NO^+ + O$	1.20e-09	0.00	0	585
2376	2i	$O^+ + NO_2 = NO_2^+ + O$	1.60e-09	0.00	0	587
2377	2i	$O^{+}(^{2}D) + N_{2} \leftrightharpoons N_{2}^{+} + O$	1.35e-10	0.00	0	585
2378	2i	$O^+(^2D) + N_2 \leftrightharpoons NO^+ + N$	1.50e-11	0.00	0	585

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2379	2i	$O^+(^3P) + N_2 \leftrightharpoons N_2^+ + O$	1.35e-10	0.00	0	585
2380	2i	$O^+(^3P) + N_2 \leftrightharpoons NO^+ + N$	1.50e-11	0.00	0	585
2381	2i	$O^+(^2D) + O_2 = O_2^+ + O$	5.67e-10	0.00	0	588
2382	2i	$O^{+}(^{2}D) + O_{2} = O^{+} + O_{2}$	2.43e-10	0.00	0	588
2383	2i	$SiO^+ + H_2 \leftrightharpoons SiHO^+ + H$	3.20 e-10	0.00	0	589
2384	2i	$SiO^+ + N \leftrightharpoons Si^+ + NO$	2.01e-10	0.00	0	590
2385	2i	$SiO^+ + N \leftrightharpoons NO^+ + Si$	9.90e-11	0.00	0	590
2386	2i	$O_2^+(X^2\Pi_g) + Ar \leftrightharpoons Ar^+ + O_2$	5.00e-10	0.00	0	591
2387	2i	$O_2^+(X^2\Pi_g) + Ar \leftrightharpoons O_2^+ + Ar$	5.00e-10	0.00	0	591
2388	2i	$O_2^+ + CH_2O \leftrightharpoons CH_2O^+ + O_2$	2.07e-09	0.00	0	574
2389	2i	$O_2^+ + CH_2O \leftrightharpoons CHO^+ + HO_2$	2.30e-10	0.00	0	574
2390	2i	$O_2^+ + HCOOH \leftrightharpoons CH_2O_2^+ + O_2$	1.17e-09	0.00	0	443
2391	2i	$O_2^+ + HCOOH \leftrightharpoons CHO_2^+ + HO_2$	6.30 e-10	0.00	0	443
2392	2i	$O_2^+ + CH_4 \leftrightharpoons CH_3O_2^+ + H$	4.41e-12	0.00	0	574
2393	2i	$O_2^+ + CH_4 \leftrightharpoons CH_2O^+ + H_2O$	9.45e-13	0.00	0	574
2394	2i	$O_2^+ + CH_4 \leftrightharpoons H_2O^+ + CH_2O$	9.45e-13	0.00	0	574
2395	2i	$O_2^+(X^2\Pi_g) + CH_4 \leftrightharpoons CH_3O_2^+ + H$	7.70e-10	0.00	0	592
2396	2i	$O_2^+(X^2\Pi_g^-) + CH_4 \leftrightharpoons CH_2O^+ + H_2O$	1.65e-10	0.00	0	592
2397	2i	$O_2^+(X^2\Pi_g) + CH_4 \leftrightharpoons H_2O^+ + CH_2O$	1.65e-10	0.00	0	592
2398	2i	$O_2^+ + CH_3OH \leftrightharpoons CH_3O^+ + HO_2$	5.00e-10	0.00	0	574
2399	2i	$O_2^+ + CH_3OH \leftrightharpoons CH_4O^+ + O_2$	5.00e-10	0.00	0	574
2400	2i	$O_2^+ + CH_5N \leftrightharpoons CH_5N^+ + O_2$	8.45 e-10	0.00	0	574
2401	2i	$O_2^+ + CH_5N \leftrightharpoons CH_4N^+ + HO_2$	4.55e-10	0.00	0	574
2402	2i	$O_2^+(X^2\Pi_g) + CO \leftrightharpoons CO^+ + O_2$	1.49e-10	0.00	0	591
2403	2i	$O_2^+(X^2\Pi_g) + CO \leftrightharpoons O_2^+ + CO$	1.00e-10	0.00	0	591
2404	2i	$O_2^+(X^2\Pi_g) + CO \leftrightharpoons CO_2^+ + O$	3.06e-11	0.00	0	585
2405	2i	$O_2^+(X^2\Pi_g) + CO_2 \leftrightharpoons CO_2^+ + O_2$	9.00e-10	0.00	0	591
2406	2i	$O_2^+(X^2\Pi_g) + CO_2 \leftrightharpoons O_2^+ + CO_2$	9.00e-10	0.00	0	591
2407	2i	$O_2^+ + C_2H_4 \leftrightharpoons C_2H_4^+ + O_2$	6.80 e-10	0.00	0	593
2408	2i	$O_2^+ + C_2H_6 \leftrightharpoons C_2H_6^+ + O_2$	1.21e-09	0.00	0	528
2409	2i	$O_2^+(X^2\Pi_g) + H_2 = O_2^+ + H_2$	6.00e-10	0.00	0	591
2410	2i	$O_2^+(X^2\Pi_g) + H_2 \leftrightharpoons HO_2^+ + H$	1.02e-09	0.00	0	585
2411	2i	$O_2^+(X^2\Pi_g) + H_2 \leftrightharpoons H_2^+ + O_2$	1.80e-10	0.00	0	585
2412	2i	$O_2^+ + H_2O_2 \leftrightharpoons H_2O_2^+ + O_2$	1.50e-09	0.00	0	554
2413	2i	$O_2^+ + H_3N \leftrightharpoons H_3N^+ + O_2$	1.00e-09	0.00	0	574
2414	2i	$O_2^+ + N \leftrightharpoons NO^+ + O$	1.20e-10	0.00	0	577
2415	2i	$O_2^+ + NO \leftrightharpoons NO^+ + O_2$	3.00e-10	0.00	0	581
2416	2i	$O_2^{-1}(X^2\Pi_g) + NO \leftrightharpoons NO^+ + O_2$	1.10e-09	0.00	0	541
2417	2i	$O_2^+(X^2\Pi_g) + NO \leftrightharpoons O_2^+ + NO$	1.10e-09	0.00	0	541
2418	2i	$O_2^+ + NO_2 \leftrightharpoons NO_2^+ + O_2$	8.20e-10	0.00	0	593
2419	2i	$O_2^+(X^2\Pi_g) + N_2 \stackrel{-}{\leftrightharpoons} N_2^+ + O_2$	4.10e-10	0.00	0	591

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2420	2i	$O_2^+(X^2\Pi_q) + N_2 \leftrightharpoons O_2^+ + N_2$	4.10e-10	0.00	0	591
2421	2i	$O_2^+(X^2\Pi_g) + O_2 \leftrightharpoons O_2^+ + O_2$	4.60 e-10	0.00	0	591
2422	2i	$Si^+ + H_2O \leftrightharpoons SiHO^+ + H$	2.30e-10	0.00	0	589
2423	2i	$\mathrm{Si^+} + \mathrm{SiH_4} \leftrightharpoons \mathrm{Si_2H^+} + \mathrm{H_2} + \mathrm{H}$	2.08e-11	0.00	0	542
2424	2i	$\mathrm{Si^+} + \mathrm{SiH_4} \leftrightharpoons \mathrm{Si_2^+} + \mathrm{H_2} + \mathrm{H_2}$	1.02e-11	0.00	0	542
2425	2i	$\mathrm{Si^+} + \mathrm{Si_2H_6} \leftrightharpoons \mathrm{Si_2H_2^+} + \mathrm{SiH_4}$	7.85e-10	0.00	0	543
2426	2i	$\mathrm{Si}^+ + \mathrm{Si}_2\mathrm{H}_6 \leftrightharpoons \mathrm{Si}_3\mathrm{H}_4^+ + \mathrm{H}_2$	2.35e-10	0.00	0	543
2427	2i	$\mathrm{Si^+} + \mathrm{O_2} \leftrightharpoons \mathrm{SiO^+} + \mathrm{O}$	9.20e-11	0.00	4000	589
2428	2i	$\mathrm{Si}_2^+ + \mathrm{Si}_2\mathrm{H}_6 \leftrightharpoons \mathrm{Si}_4\mathrm{H}_2^+ + \mathrm{H}_2 + \mathrm{H}_2$	3.06e-10	0.00	0	543
2429	2i	$\operatorname{Si}_{2}^{+} + \operatorname{Si}_{2}\operatorname{H}_{6} \leftrightharpoons \operatorname{Si}_{4}\operatorname{H}_{3}^{+} + \operatorname{H}_{2} + \operatorname{H}$	1.53e-10	0.00	0	543
2430	2i	$\mathrm{Si}_2^+ + \mathrm{Si}_2\mathrm{H}_6 \leftrightharpoons \mathrm{Si}_4\mathrm{H}_4^+ + \mathrm{H}_2$	1.30e-10	0.00	0	543
2431	2i	$\operatorname{Si}_{2}^{+} + \operatorname{Si}_{2}\operatorname{H}_{6} \leftrightharpoons \operatorname{Si}_{3}\operatorname{H}_{2}^{+} + \operatorname{Si}\operatorname{H}_{4}$	1.22e-10	0.00	0	543
2432	2i	$\mathrm{Si}_{2}^{+} + \mathrm{Si}_{2}\mathrm{H}_{6} \leftrightharpoons \mathrm{Si}_{3}\mathrm{H}_{3}^{+} + \mathrm{SiH}_{3}$	5.36e-11	0.00	0	543
2433	2i	$\mathrm{Ti^+} + \mathrm{C_2H_6} \leftrightharpoons \mathrm{TiC_2H_4^+} + \mathrm{H_2}$	7.50e-11	0.00	0	594
2434	2i	$Ti^+ + NO \leftrightharpoons TiO^+ + N$	9.50e-11	0.00	0	595
2435	2i	$Ti^+ + O_2 \leftrightharpoons TiO^+ + O$	5.00e-10	0.00	0	595
2436	2i	$C^- + HCN \leftrightharpoons CN^- + CH$	1.10e-09	0.00	0	596
2437	2i	$C^- + CO \leftrightharpoons C_2O + e^-$	4.10e-10	0.00	0	597
2438	2i	$C^- + CO_2 \leftrightharpoons CO + CO + e^-$	4.70e-11	0.00	0	597
2439	2i	$C^- + H_2 \leftrightharpoons CH_2 + e^-$	1.00e-13	0.00	0	597
2440	2i	$C^- + SiH_4 \leftrightharpoons SiH_3^- + CH$	6.20e-11	0.00	0	596
2441	2i	$C^- + N_2O \leftrightharpoons CO + N_2 + e^-$	9.00e-10	0.00	0	597
2442	2i	$C^- + O_2 \leftrightharpoons O^- + CO$	3.40e-10	0.00	0	597
2443	2i	$C^- + O_2 \leftrightharpoons CO_2 + e^-$	6.00e-11	0.00	0	597
2444	2i	$CH_3O^- + HCN \leftrightharpoons CN^- + CH_3OH$	3.30e-09	0.00	0	598
2445	2i	$CH_3O^- + C_2H_2O \leftrightharpoons C_2HO^- + CH_3OH$	1.40e-09	0.00	0	599
2446	2i	$CH_3O^- + CH_3CN \leftrightharpoons C_2H_2N^- + CH_3OH$	3.50e-09	0.00	0	465
2447	2i	$CH_3O^- + C_2H_4O \leftrightharpoons C_2H_3O^- + CH_3OH$	2.00e-09	0.00	0	598
2448	2i	$CH_3O^- + C_2H_5OH \leftrightharpoons C_2H_5O^- + CH_3OH$	3.30e-09	0.00	0	598
2449	2i	$CH_4N^- + C_2H_2 \leftrightharpoons C_2H^- + CH_5N$	1.33e-09	0.00	0	464
2450	2i	$CH_4N^- + H_2 \leftrightharpoons H^- + CH_5N$	2.00e-10	0.00	0	600
2451	2i	$CN^- + C_2H_4O \leftrightharpoons CNO^- + C_2H_4$	9.99e-13	0.00	0	458
2452	2i	$CN^- + H \leftrightharpoons HCN + e^-$	1.30e-09	0.00	0	601
2453	2i	$CN^- + HNO_3 \leftrightharpoons NO_3^- + HCN$	2.00e-09	0.00	0	602
2454	2i	$CO_3^- + H \leftrightharpoons HO^- + CO_2$	1.70e-10	0.00	0	603
2455	2i	$CO_3^- + NO \leftrightharpoons NO_2^- + CO_2$	1.00e-11	0.00	0	604
2456	2i	$CO_3^- + NO_2 \leftrightharpoons NO_3^- + CO_2$	2.00e-10	0.00	0	605
2457	2i	$CO_3^- + O \leftrightharpoons O_2^- + CO_2$	1.10e-10	0.00	0	606
2458	2i	$CO_4^- + H \leftrightharpoons CO_3^- + HO$	1.65e-10	0.00	0	603
2459	2i	$CO_4^- + H \leftrightharpoons HO^- + CO + O_2$	5.50e-11	0.00	0	603
2460	2i	$CO_4^- + NO \leftrightharpoons NO_3^- + CO_2$	4.80e-11	0.00	0	607

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2461	2i	$CO_4^- + O \leftrightharpoons CO_3^- + O_2$	7.00e-11	0.00	0	606
2462	2i	$CO_4^{\frac{1}{4}} + O = O^{-3} + CO_2 + O_2$	3.50e-11	0.00	0	606
2463	2i	$CO_4^{\frac{1}{4}} + O \leftrightharpoons O_3^{-} + CO_2$	3.50e-11	0.00	0	606
2464	2i	$CO_4^{\frac{1}{2}} + O_3 = O_3^{-} + CO_2 + O_2$	1.30e-10	0.00	0	605
2465	2i	$C_2^- + HCN \leftrightharpoons CN^- + C_2H$	2.00e-09	0.00	0	536
2466	2i	$C_2^- + O_2 \leftrightharpoons CO_2 + C + e^-$	2.10e-11	0.00	0	608
2467	2i	$C_2^-H^- + HCN \leftrightharpoons CN^- + C_2H_2$	3.90e-09	0.00	0	465
2468	2i	$C_2H^- + CH_3NO_2 \leftrightharpoons CH_2NO_2^- + C_2H_2$	2.38e-09	0.00	0	462
2469	2i	$C_2H^- + CH_3NO_2 \leftrightharpoons NO_2^- + C_3H_4$	1.26e-10	0.00	0	462
2470	2i	$C_2H^- + CH_3OH \leftrightharpoons CH_3O^- + C_2H_2$	5.00e-11	0.00	0	609
2471	2i	$C_2H^- + CH_3CN \leftrightharpoons C_2H_2N^- + C_2H_2$	1.50e-09	0.00	0	465
2472	2i	$C_2H^- + C_2H_5OH \leftrightharpoons C_2H_5O^- + C_2H_2$	1.00e-10	0.00	0	609
2473	2i	$C_2H^- + O_3 \leftrightharpoons O_3^- + C_2H$	2.00e-12	0.00	0	610
2474	2i	$C_2H_2^- + O_2 \leftrightharpoons O_2^- + C_2H_2$	3.00e-10	0.00	0	611
2475	2i	$C_2H_2N^- + H \leftrightharpoons CH_3CN + e^-$	1.90e-09	0.00	0	612
2476	2i	$C_2H_2N^- + HNO_3 \leftrightharpoons NO_3^- + CH_3CN$	1.40e-09	0.00	0	602
2477	2i	$C_2H_2N^- + NO_2 \leftrightharpoons NO_2^- + CH_2CN$	1.00e-09	0.00	0	602
2478	2i	$H^- + HCN \leftrightharpoons CN^- + H_2$	1.50e-08	0.00	0	465
2479	2i	$\mathrm{H^-} + \mathrm{CH_3NO_2} \leftrightharpoons \mathrm{CH_2NO_2^-} + \mathrm{H_2}$	1.22e-08	0.00	0	462
2480	2i	$\mathrm{H^-} + \mathrm{CH_3NO_2} \leftrightarrows \mathrm{NO_2^-} + \mathrm{CH_4}$	6.45 e-10	0.00	0	462
2481	2i	$H^- + CO = CHO + e^-$	5.00e-11	0.00	0	613
2482	2i	$\mathrm{H^-} + \mathrm{C_2H_2} \leftrightharpoons \mathrm{C_2H^-} + \mathrm{H_2}$	4.42e-09	0.00	0	464
2483	2i	$\mathrm{H^-} + \mathrm{CH_3CN} \leftrightharpoons \mathrm{C_2H_2N^-} + \mathrm{H_2}$	1.30e-08	0.00	0	465
2484	2i	$H^- + H \leftrightharpoons H_2 + e^-$	1.80e-09	0.00	0	612
2485	2i	$\mathrm{H^-} + \mathrm{H_2O} \leftrightharpoons \mathrm{HO^-} + \mathrm{H_2}$	3.70e-09	0.00	0	472
2486	2i	$\mathrm{H^-} + \mathrm{H_3N} \leftrightharpoons \mathrm{H_2N^-} + \mathrm{H_2}$	8.80e-13	0.00	0	600
2487	2i	$\mathrm{H}^- + \mathrm{SiH}_4 \leftrightharpoons \mathrm{SiH}_3^- + \mathrm{H}_2$	5.70e-10	0.00	0	614
2488	2i	$H^- + NO \leftrightharpoons HNO + e^-$	4.60e-10	0.00	0	613
2489	2i	$\mathrm{H^-} + \mathrm{NO}_2 \leftrightharpoons \mathrm{NO}_2^- + \mathrm{H}$	2.90e-09	0.00	0	615
2490	2i	$\mathrm{H^-} + \mathrm{N_2O} \leftrightharpoons \mathrm{HO^-} + \mathrm{N_2}$	1.10e-09	0.00	0	613
2491	2i	$\mathrm{H}^- + \mathrm{O}_2 \leftrightharpoons \mathrm{HO}_2 + e^-$	1.20e-09	0.00	0	613
2492	2i	$HO^- + HCN \rightleftharpoons CN^- + H_2O$	4.10e-09	0.00	0	465
2493	2i	$HO^- + HCOOH \leftrightharpoons CHO_2^- + H_2O$	2.20e-09	0.00	0	616
2494	2i	$\mathrm{HO^-} + \mathrm{CH_3NO_2} \leftrightharpoons \mathrm{CH_2NO_2^-} + \mathrm{H_2O}$	3.61e-08	0.00	0	462
2495	2i	$\mathrm{HO^-} + \mathrm{CH_3NO_2} \leftrightharpoons \mathrm{NO_2^-} + \mathrm{CH_3OH}$	1.90e-09	0.00	0	462
2496	2i	$HO^- + CH_3OH \leftrightharpoons CH_3O^- + H_2O$	2.20e-09	0.00	0	616
2497	2i	$\mathrm{HO^-} + \mathrm{C_2H_2} \leftrightharpoons \mathrm{C_2H^-} + \mathrm{H_2O}$	2.18e-09	0.00	0	464
2498	2i	$HO^- + C_2H_2O \leftrightharpoons C_2HO^- + H_2O$	2.20e-09	0.00	0	616
2499	2i	$HO^- + CH_3CN \leftrightharpoons C_2H_2N^- + H_2O$	4.40e-09	0.00	0	465
2500	2i	$\mathrm{HO^-} + \mathrm{C_2H_4} \leftrightharpoons \mathrm{C_2H_3^-} + \mathrm{H_2O}$	3.00e-11	0.00	0	611
2501	2i	$HO^- + C_2H_4O \leftrightharpoons C_2H_3O^- + H_2O$	3.10e-09	0.00	0	617

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2502	2i	$\mathrm{HO^-} + \mathrm{CH_3OCHO} \leftrightharpoons \mathrm{CHO_2^-} + \mathrm{CH_3OH}$	8.40e-10	0.00	0	618
2503	2i	$HO^- + CH_3OCHO = CH_3O^- + H_2O + CO$	6.60e-10	0.00	0	618
2504	2i	$HO^- + C_2H_5OH \leftrightharpoons C_2H_5O^- + H_2O$	2.70e-09	0.00	0	616
2505	2i	$HO^- + H \leftrightharpoons H_2O + e^-$	1.40e-09	0.00	0	619
2506	2i	$\mathrm{HO^-} + \mathrm{H_3N} \leftrightharpoons \mathrm{H_2N^-} + \mathrm{H_2O}$	5.00e-12	0.00	0	620
2507	2i	$HO^- + SiH_4 \leftrightharpoons SiH_3^- + H_2O$	8.71e-10	0.00	0	614
2508	2i	$\mathrm{HO^-} + \mathrm{SiH_4} \leftrightharpoons \mathrm{SiH_3O^-} + \mathrm{H_2}$	4.29e-10	0.00	0	614
2509	2i	$HO^- + N \leftrightharpoons HNO + e^-$	9.99e-12	0.00	0	621
2510	2i	$HO^- + NO_2 \leftrightharpoons NO_2^- + HO$	1.10e-09	0.00	0	622
2511	2i	$HO^- + O \leftrightharpoons HO_2 + e^-$	2.00e-10	0.00	0	621
2512	2i	$HO^- + O_3 \leftrightharpoons O_3^- + HO$	9.00e-10	0.00	0	622
2513	2i	$H_2N^- + HCN \leftrightharpoons CN^- + H_3N$	4.80e-09	0.00	0	465
2514	2i	$H_2N^- + CH_3NO_2 \leftrightharpoons CH_2NO_2^- + H_3N$	4.61e-09	0.00	0	462
2515	2i	$H_2N^- + CH_3NO_2 \leftrightharpoons NO_2^- + CH_5N$	2.23e-10	0.00	0	462
2516	2i	$H_2N^- + CH_5N \leftrightharpoons CH_4N^- + H_3N$	1.01e-10	0.00	0	600
2517	2i	$H_2N^- + CO_2 \leftrightharpoons CNO^- + H_2O$	9.30e-10	0.00	0	463
2518	2i	$H_2N^- + C_2H_2 \leftrightharpoons C_2H^- + H_3N$	1.84e-09	0.00	0	464
2519	2i	$H_2N^- + CH_3CN \leftrightharpoons C_2H_2N^- + H_3N$	5.10e-09	0.00	0	465
2520	2i	$H_2N^- + C_2H_4O \leftrightharpoons CN^- + CH_2O + H_2 + H_2$	1.20e-10	0.00	0	617
2521	2i	$H_2N^- + C_2H_4O \leftrightharpoons C_2H_4NO^- + H_2$	3.00e-11	0.00	0	617
2522	2i	$H_2N^- + NO_2 \leftrightharpoons NO_2^- + H_2N$	1.00e-09	0.00	0	615
2523	2i	$H_2N^- + N_2O \leftrightharpoons N_3^- + H_2O$	2.09e-10	0.00	0	624
2524	2i	$H_2N^- + O_2 \leftrightharpoons HO^- + HNO$	4.60e-11	0.00	0	625
2525	2i	$NO^- + NO_2 \leftrightharpoons NO_2^- + NO$	7.40e-10	0.00	0	626
2526	2i	$NO^- + O_2 \leftrightharpoons O_2^- + NO$	5.00e-10	0.00	0	626
2527	2i	$NO_2^- + H \leftrightharpoons HNO_2 + e^-$	1.85e-10	0.00	0	603
2528	2i	$NO_2^- + H \leftrightharpoons HO^- + NO$	1.85e-10	0.00	0	603
2529	2i	$NO_2^- + HNO_3 \leftrightharpoons NO_3^- + HNO_2$	1.60e-09	0.00	0	114
2530	2i	$NO_2^- + O_3 \leftrightharpoons NO_3^- + O_2$	1.20e-10	0.00	0	622
2531	2i	$NO_2^- + O_3 \leftrightharpoons O_3^- + NO_2$	9.00e-11	0.00	0	610
2532	2i	$O^- + HCN \leftrightharpoons CN^- + HO$	3.70e-09	0.00	0	536
2533	2i	$O^- + CH_4 \leftrightharpoons HO^- + CH_3$	1.10e-10	0.00	0	627
2534	2i	$O^- + CO \leftrightharpoons CO_2 + e^-$	7.30e-10	0.00	0	628
2535	2i	$O^- + C_2H_2 \leftrightharpoons C_2H_2O + e^-$	1.31e-09	0.00	0	627
2536	2i	$O^- + C_2H_2 \leftrightharpoons C_2H^- + HO$	8.07e-10	0.00	0	627
2537	2i	$O^- + C_2H_2 \leftrightharpoons C_2HO^- + H$	6.54e-11	0.00	0	627
2538	2i	$O^- + CH_3CN \leftrightharpoons C_2H_2N^- + HO$	3.50e-09	0.00	0	602
2539	2i	$O^- + C_2H_4 \leftrightharpoons C_2H_4O + e^-$	4.10e-10	0.00	0	627
2540	2i	$O^- + C_2H_4 \leftrightharpoons C_2H_2^- + H_2O$	1.89e-10	0.00	0	627
2541	2i	$O^- + C_2H_4 \leftrightharpoons C_2H_3O^- + H$	1.95e-11	0.00	0	627
2542	2i	$O^- + C_2H_6 \leftrightharpoons HO^- + C_2H_5$	7.00e-10	0.00	0	629

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2543	2i	$O^- + H_2 \leftrightharpoons H_2O + e^-$	7.01e-10	0.00	0	627
2544	2i	$O^- + H_2 \leftrightharpoons HO^- + H$	2.92e-11	0.00	0	627
2545	2i	$O^- + H_3N \leftrightharpoons HO^- + H_2N$	1.50e-09	0.00	0	611
2546	2i	$O^- + N \leftrightharpoons NO + e^-$	2.20e-10	0.00	0	630
2547	2i	$O^- + NO \leftrightharpoons NO_2 + e^-$	3.10e-10	-0.83	0	631
2548	2i	$O^- + NO_2 \leftrightharpoons NO_2^- + O$	1.25 e-09	0.00	0	632
2549	2i	$O^- + N_2O \leftrightharpoons NO^- + NO$	2.20e-10	0.00	0	633
2550	2i	$O^- + O \leftrightharpoons O_2 + e^-$	1.90e-10	0.00	0	606
2551	2i	$O^- + O_2 \leftrightharpoons O_2^- + O$	7.00e-13	0.00	0	634
2552	2i	$O^- + O_2(a^1 \Delta_g) \leftrightharpoons O_3 + e^-$	3.00e-10	0.00	0	635
2553	2i	$O^- + O_3 \leftrightharpoons O_2 + O_2 + e^-$	3.01e-10	0.00	0	636
2554	2i	$O^- + O_3 \leftrightharpoons O_3^- + O$	1.99e-10	0.00	0	636
2555	2i	$O^- + O_3 \leftrightharpoons O_2^- + O_2$	1.02e-11	0.00	0	636
2556	2i	$O_2^- + H \leftrightharpoons HO_2 + e^-$	1.40e-09	0.00	0	603
2557	2i	$O_2^- + H \leftrightharpoons H^- + O_2$	1.40e-09	0.00	0	603
2558	2i	$O_2^- + N \leftrightharpoons NO_2 + e^-$	4.00e-10	0.00	0	630
2559	2i	$O_2^- + NO_2 \leftrightharpoons NO_2^- + O_2$	7.00e-10	0.00	0	622
2560	2i	$O_2^- + O \leftrightharpoons O_3 + e^-$	1.50e-10	0.00	0	603
2561	2i	$O_2^- + O \leftrightharpoons O^- + O_2$	1.50e-10	0.00	0	603
2562	2i	$O_2^- + O_3 \leftrightharpoons O_3^- + O_2$	7.80e-10	0.00	0	637
2563	2i	$O_3^- + CO_2 \leftrightharpoons CO_3^- + O_2$	5.50e-10	0.00	0	628
2564	2i	$O_3^- + H \leftrightharpoons HO^- + O_2$	8.40e-10	0.00	0	603
2565	2i	$O_3^- + NO \leftrightharpoons NO_2^- + O_2$	1.65e-12	0.00	0	604
2566	2i	$O_3^- + NO_2 \leftrightharpoons NO_3^- + O_2$	2.80e-10	0.00	0	638
2567	2i	$O_3 + O = O_2 + O_2$	2.50e-10	0.00	0	606
2568	2i	$Na^+ + K \leftrightharpoons K^+ + Na$	1.00e-11	0.00	0	100
2569	2i	$Na + H = Na^+ + H^-$	1.00e-11	0.00	50900	100
2570	pi	$C + \gamma \rightarrow C^+ + e^-$		• • •	• • •	639
2571	pi :	$C(^{1}D) + \gamma \rightarrow C^{+} + e^{-}$	• • •	• • •		640
2572	pi :	$C(^{1}S) + \gamma \rightarrow C^{+} + e^{-}$ $H + \gamma \rightarrow H^{+} + e^{-}$	• • •	• • •		640
2573	pi ri	$H + \gamma \rightarrow H^+ + e^-$ $H + \gamma \rightarrow H + e^+$	•••			641
$2574 \\ 2575$	pi ri	$N + \gamma \rightarrow N^+ + e^-$	•••		• • •	642 643
2576	pi pi	$0 + \gamma \to 0^+ + e^-$	•••	• • •		644
2570 2577	-	$O(^{1}D) + \gamma \rightarrow O^{+} + e^{-}$				645
$\frac{2577}{2578}$	pi pi	$O(^{1}S) + \gamma \rightarrow O^{+} + e^{-}$ $O(^{1}S) + \gamma \rightarrow O^{+} + e^{-}$				645
2579	рі pi	$H^- + \gamma \rightarrow H^+ + e^- + e^-$				646
2580	pi pi	$\mathrm{H^-} + \gamma \rightarrow \mathrm{H} + e^-$				646
2580 2581	$^{\mathrm{pr}}$	$C_2 + \gamma \rightarrow C(^1D) + C(^1D)$				647
2582	pi pi	$C_2 + \gamma \rightarrow C_2^+ + e^-$				647
2583	pi	$CH + \gamma \rightarrow CH^+ + e^-$				648
_500	L'1	, ,				0.10

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2584	$_{\mathrm{pd}}$	$CH + \gamma \rightarrow C(^{1}S) + H$				648
2585	pd	$CH + \gamma \rightarrow C(^{1}D) + H$				648
2586	pd	$CH + \gamma \rightarrow C + H$				648
2587	pd	$CN + \gamma \rightarrow C + N$				649
2588	pi	$CO + \gamma \rightarrow CO^{+} + e^{-}$				650
2589	pi	$CO + \gamma \rightarrow C^+ + O + e^-$				651
2590	pi	$CO + \gamma \rightarrow O^+ + C + e^-$				651
2591	pd	$CO + \gamma \rightarrow C + O$				652
2592	pd	$CO + \gamma \rightarrow C(^{1}D) + O(^{1}D)$				652
2593	pd	$H_2 + \gamma \rightarrow H + H$				653
2594	pi	$\mathrm{H_2} + \gamma \rightarrow \mathrm{H_2^+} + e^-$				653
2595	pi	$H_2 + \gamma \rightarrow H^+ + H + e^-$				653
2596	pd	$N_2 + \gamma \rightarrow N + N$				654
2597	pi	$N_2 + \gamma \rightarrow N^+ + N + e^-$				654
2598	pi	$N_2 + \gamma \to N_2^+ + e^-$				654
2599	pi	$NO + \gamma \rightarrow NO^+ + e^-$				655
2600	pi	$NO + \gamma \rightarrow O^+ + N + e^-$				655
2601	pi	$NO + \gamma \rightarrow N^+ + O + e^-$				655
2602	pd	$NO + \gamma \rightarrow N + O$				655
2603	pd	$O_2 + \gamma \rightarrow O + O$				656
2604	pd	$O_2 + \gamma \rightarrow O + O(^1D)$				656
2605	pi	$O_2 + \gamma \rightarrow O^+ + O + e^-$				656
2606	pd	$O_2 + \gamma \rightarrow O(^1S) + O(^1S)$				656
2607	pi	$O_2 + \gamma \rightarrow O_2^+ + e^-$				656
2608	pd	$HO + \gamma \rightarrow O + H$				657
2609	pd	$HO + \gamma \rightarrow O(^{1}S) + H$				657
2610	pi	$HO + \gamma \rightarrow HO^+ + e^-$				657
2611	pd	$HO + \gamma \rightarrow O(^{1}D) + H$				657
2612	pd	$CO_2 + \gamma \rightarrow CO + O(^1D)$				658
2613	pi	$CO_2 + \gamma \rightarrow CO_2^+ + e^-$				658
2614	pi	$CO_2 + \gamma \rightarrow CO^+ + O + e^-$				658
2615	pi	$CO_2 + \gamma \rightarrow O^+ + CO + e^-$				658
2616	pi	$CO_2 + \gamma \rightarrow C^+ + O_2 + e^-$				658
2617	pd	$CO_2 + \gamma \rightarrow CO + O$				658
2618	pd	$H_2O + \gamma \rightarrow HO + H$				659
2619	pd	$H_2O + \gamma \rightarrow H_2 + O(^1D)$				659
2620	pd	$H_2O + \gamma \rightarrow O + H + H$				659
2621	pi	$H_2O + \gamma \rightarrow HO^+ + H + e^-$				659
2622	pi	$H_2O + \gamma \rightarrow O^+ + H_2 + e^-$				659
2623	pi	$H_2O + \gamma \rightarrow H^+ + HO + e^-$				659
2624	pi	$H_2O + \gamma \rightarrow H_2O^+ + e^-$				659

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2625	pd	$HCN + \gamma \rightarrow CN + H$				660
2626	pi	$HCN + \gamma \rightarrow CHN^+ + e^-$				660
2627	pd	$HO_2 + \gamma \rightarrow HO + O$				661
2628	pd	$N_2O + \gamma \rightarrow N_2 + O(^1S)$				662
2629	pd	$N_2O + \gamma \rightarrow N_2 + O(^1D)$				662
2630	pd	$H_2N + \gamma \rightarrow HN + H$		• • •	• • •	663
2631	pi	$NO_2 + \gamma \rightarrow NO_2^+ + e^-$				664
2632	pd	$NO_2 + \gamma \rightarrow NO + O(^1D)$		• • •	• • •	664
2633	pd	$NO_2 + \gamma \rightarrow NO + O$				664
2634	pd	$O_3 + \gamma \rightarrow O_2 + O$		• • •	• • •	665
2635	pd	$O_3 + \gamma \rightarrow O_2 + O(^1S)$	• • •			665
2636	pi	$C_2H_2 + \gamma \to C_2H_2^+ + e^-$				666
2637	pi	$C_2H_2 + \gamma \to C_2H^+ + H + e^-$				666
2638	pd	$C_2H_2 + \gamma \to C_2 + H_2$				666
2639	pd	$C_2H_2 + \gamma \rightarrow C_2H + H$	• • •	• • •		666
2640	pd	$CH_2O + \gamma \rightarrow CHO + H$	• • •	• • •		667
2641	pd	$CH_2O + \gamma \rightarrow CO + H_2$	• • •			667
2642	pd	$CH_2O + \gamma \rightarrow CO + H + H$	• • •			667
2643	pi	$CH_2O + \gamma \rightarrow CH_2O^+ + e^-$	• • •	• • •		667
2644	pi	$CH_2O + \gamma \rightarrow CHO^+ + H + e^-$	• • •			667
2645	pi	$CH_2O + \gamma \rightarrow CO^+ + H_2 + e^-$	• • •	• • •		667
2646	pd	$H_2O_2 + \gamma \rightarrow HO + HO$	• • •			667
2647	pd	$\text{HNCO} + \gamma \rightarrow \text{HN} + \text{CO}$				668
2648	pd	$\text{HNCO} + \gamma \rightarrow \text{NCO} + \text{H}$	• • •			668
2649	pd	$HNO_2 + \gamma \rightarrow HO + NO$		• • •		669
2650	pd	$H_3N + \gamma \rightarrow H_2N + H$		• • •		670
2651	pd	$H_3N + \gamma \rightarrow HN^* + H_2$	• • •	• • •		670
2652	pd	$H_3N + \gamma \rightarrow HN + H + H$	• • •	• • •		670
2653	pi	$H_3N + \gamma \rightarrow H_3N^+ + e^-$	• • •	• • •		670
2654	pi	$H_3N + \gamma \rightarrow H_2N^+ + H + e^-$	• • •	• • •		670
2655	pi	$H_3N + \gamma \rightarrow HN^+ + H_2 + e^-$		• • •		670
2656	pd	$NO_3 + \gamma \rightarrow NO_2 + O$	• • •	• • •		671
2657	pd	$NO_3 + \gamma \rightarrow NO + O_2$	• • •	• • •		671
2658	pd	$CH_4 + \gamma \rightarrow CH_2^* + H_2$	• • •			672
2659	pd	$CH_4 + \gamma \rightarrow CH_3 + H$	• • •	• • •		672
2660	pd	$CH_4 + \gamma \rightarrow CH_2 + H + H$	• • •			672
2661	pi	$CH_4 + \gamma \rightarrow CH_4^+ + e^-$	• • •			672
2662	pi	$\mathrm{CH_4} + \gamma \to \mathrm{CH_3^+} + \mathrm{H} + e^-$				672
2663	pi	$CH_4 + \gamma \rightarrow CH_2^+ + H_2 + e^-$	• • •			672
2664	pd	$CH_4 + \gamma \rightarrow CH + H_2 + H$				672
2665	pd	$\mathrm{HCOOH} + \gamma \rightarrow \mathrm{CO}_2 + \mathrm{H}_2$				673

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2666	pi	$\text{HCOOH} + \gamma \rightarrow \text{CH}_2\text{O}_2^+ + e^-$				673
2667	pi	$\text{HCOOH} + \gamma \rightarrow \text{CHO}^+ + \text{HO} + e^-$				673
2668	pd	$\text{HCOOH} + \gamma \rightarrow \text{CHO} + \text{HO}$				673
2669	pd	$HNO_3 + \gamma \rightarrow NO_2 + HO$				674
2670	pi	$C_2H_4 + \gamma \to C_2H_4^+ + e^-$				675
2671	pi	$C_2H_4 + \gamma \rightarrow C_2H_2^+ + H_2 + e^-$				675
2672	pi	$C_2H_4 + \gamma \to C_2H_3^+ + H + e^-$				675
2673	pd	$C_2H_4 + \gamma \rightarrow C_2H_2 + H + H$	• • •		• • •	675
2674	pd	$C_2H_4 + \gamma \to C_2H_2 + H_2$	• • •	• • •	• • •	675
2675	pd	$C_2H_6 + \gamma \rightarrow CH_3 + CH_3$	• • •	• • •	• • •	676
2676	pd	$C_2H_6 + \gamma \rightarrow C_2H_5 + H$	• • •	• • •	• • •	676
2677	pd	$C_2H_6 + \gamma \rightarrow CH_2^* + CH_4$	• • •	• • •	• • •	676
2678	pi	$C_2H_6 + \gamma \to C_2H_6^+ + e^-$				676
2679	pd	$C_2H_6 + \gamma \to C_2H_4 + H_2$	• • •	• • •	• • •	676
2680	pd	$C_2H_4O + \gamma \rightarrow CH_4 + CO$	• • •	• • •	• • •	677
2681	pd	$C_2H_4O + \gamma \rightarrow CH_3 + CHO$	• • •	• • •	• • •	677
2682	pd	$CH_3OH + \gamma \rightarrow CH_3 + HO$				678
2683	pi	$CH_3OH + \gamma \rightarrow CH_4O^+ + e^-$				678
2684	pd	$CH_3OH + \gamma \rightarrow CH_2O + H_2$				678
2685	pd	$C_4H_2 + \gamma \to C_2H_2 + C_2$				687
2686	pd	$C_4H_2 + \gamma \to C_2H + C_2H$	• • •	• • •	• • •	687
2687	pd	$C_4H_2 + \gamma \rightarrow C_4H + H$	• • •		• • •	687
2688	pd	$C_4H_4 + \gamma \to C_4H_2 + H_2$	• • •	• • •	• • •	688
2689	pd	$C_4H_4 + \gamma \rightarrow C_2H_2 + C_2H_2$				688
2690	pi	$Na + \gamma \rightarrow Na^+ + e^-$				679
2691	pi	$K + \gamma \rightarrow K^+ + e^-$	• • •	• • •	• • •	680
2692	pd	$HCl + \gamma \rightarrow H + Cl$	• • •	• • •	• • •	681
2693	pd	$N_2O_3 + \gamma \rightarrow NO_2 + NO$	• • •	• • •	• • •	684
2694	cr	$C + CR \rightarrow C^{+} + e^{-} + CR$	• • •	• • •	• • •	682
2695	cr	$Fe + CR \rightarrow Fe^+ + e^- + CR$	• • •		• • •	682
2696	cr	$H + CR \rightarrow H^+ + e^- + CR$	• • •	• • •	• • •	682
2697	cr	$He + CR \rightarrow He^+ + e^- + CR$	• • •	• • •	• • •	682
2698	cr	$Mg + CR \rightarrow Mg^+ + e^- + CR$	• • •	• • •	• • •	682
2699	cr	$N + CR \rightarrow N^{+} + e^{-} + CR$	• • •	• • •	• • •	682
2700	cr	$O + CR \rightarrow O^{+} + e^{-} + CR$	• • •	• • •	• • •	682
2701	cr	$Si + CR \rightarrow Si^+ + e^- + CR$	• • •	• • •	• • •	682
2702	cr	$C_2 + CR \rightarrow C + C + CR$				682
2703	cr	$CH + CR \rightarrow C + H + CR$	• • •	• • •	• • •	682
2704	cr	$CN + CR \rightarrow C + N + CR$	• • •	• • •	• • •	682
2705	cr	$CO + CR \rightarrow C + O + CR$				682
2706	cr	$CO + CR \rightarrow CO^{+} + e^{-} + CR$	• • •		• • •	682

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2707	cr	$H_2 + CR \rightarrow H + H + CR$				682
2708	cr	$H_2 + CR \to H^+ + H + e^- + CR$				682
2709	cr	$\mathrm{H_2} + \mathrm{CR} \rightarrow \mathrm{H^+} + \mathrm{H^-} + \mathrm{CR}$				682
2710	cr	$\mathrm{H}_2 + \mathrm{CR} \to \mathrm{H}_2^+ + e^- + \mathrm{CR}$				682
2711	cr	$N_2 + CR \rightarrow N + N + CR$				682
2712	cr	$HN + CR \rightarrow N + H + CR$				682
2713	cr	$NO + CR \rightarrow N + O + CR$				682
2714	cr	$NO + CR \rightarrow NO^+ + e^- + CR$				682
2715	cr	$O_2 + CR \rightarrow O + O + CR$			• • •	682
2716	cr	$O_2 + CR \rightarrow O_2^+ + e^- + CR$	• • •	• • •	• • •	682
2717	cr	$HO + CR \rightarrow O + H + CR$				682
2718	cr	$SiH + CR \rightarrow Si + H + CR$	• • •	• • •	• • •	682
2719	cr	$SiO + CR \rightarrow Si + O + CR$			• • •	682
2720	cr	$C_2H + CR \rightarrow C_2 + H + CR$			• • •	682
2721	cr	$C_2N + CR \rightarrow C + CN + CR$			• • •	682
2722	cr	$C_2O + CR \rightarrow C_2 + O + CR$			• • •	682
2723	cr	$C_2O + CR \rightarrow CO + C + CR$			• • •	682
2724	cr	$CH_2 + CR \rightarrow CH_2^+ + e^- + CR$			• • •	682
2725	cr	$CO_2 + CR \rightarrow CO + O + CR$			• • •	682
2726	cr	$H_2O + CR \rightarrow HO + H + CR$			• • •	682
2727	cr	$HCN + CR \rightarrow CN + H + CR$			• • •	682
2728	cr	$CHO + CR \rightarrow CO + H + CR$			• • •	682
2729	cr	$CHO + CR \rightarrow CHO^{+} + e^{-} + CR$			• • •	682
2730	cr	$HNC + CR \rightarrow CN + H + CR$			• • •	682
2731	cr	$\text{HNO} + \text{CR} \rightarrow \text{HNO}^+ + e^- + \text{CR}$			• • •	682
2732	cr	$N_2O + CR \rightarrow NO + N + CR$			• • •	682
2733	cr	$H_2N + CR \rightarrow HN + H + CR$			• • •	682
2734	cr	$H_2N + CR \rightarrow H_2N^+ + e^- + CR$			• • •	682
2735	cr	$NO_2 + CR \rightarrow NO + O + CR$			• • •	682
2736	cr	$HO_2 + CR \rightarrow O + HO + CR$			• • •	682
2737	cr	$HO_2 + CR \rightarrow O_2 + H + CR$			• • •	682
2738	cr	$CNO + CR \rightarrow CN + O + CR$			• • •	682
2739	cr	$SiH_2 + CR \rightarrow SiH + H + CR$			• • •	682
2740	cr	$C_2H_2 + CR \rightarrow C_2H + H + CR$			• • •	682
2741	cr	$C_2H_2 + CR \to C_2H_2^+ + e^- + CR$			• • •	682
2742	cr	$CH_3 + CR \rightarrow CH_2 + H + CR$			• • •	682
2743	cr	$CH_3 + CR \rightarrow CH_3^+ + e^- + CR$				682
2744	cr	$CH_2O + CR \rightarrow CO + H_2 + CR$			• • •	682
2745	cr	$H_2O_2 + CR \rightarrow HO + HO + CR$			• • •	682
2746	cr	$H_3N + CR \rightarrow HN + H_2 + CR$			• • •	682
2747	cr	$H_3N + CR \rightarrow H_2N + H + CR$			• • •	682

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2748	cr	$H_3N + CR \rightarrow H_3N^+ + e^- + CR$				682
2749	cr	$C_2H_2O + CR \rightarrow CH_2 + CO + CR$				682
2750	cr	$C_2H_2O + CR \to C_2H_2O^+ + e^- + CR$				682
2751	cr	$C_2H_3 + CR \rightarrow C_2H_2 + H + CR$				682
2752	cr	$CH_2O_2 + CR \rightarrow CHO + HO + CR$				682
2753	cr	$\mathrm{CH_2O_2} + \mathrm{CR} \to \mathrm{CH_2O_2^+} + e^- + \mathrm{CR}$				682
2754	cr	$CH_3N + CR \rightarrow HCN + H_2 + CR$				682
2755	cr	$CH_4 + CR \rightarrow CH_2 + H_2 + CR$	• • •			682
2756	cr	$HC_3N + CR \rightarrow C_2H + CN + CR$	• • •			682
2757	cr	$SiH_4 + CR \rightarrow SiH_2 + H_2 + CR$	• • •	• • •		682
2758	cr	$C_2H_3N + CR \rightarrow CH_3 + CN + CR$	• • •			682
2759	cr	$C_2H_3N + CR \to C_2H_3N^+ + e^- + CR$	• • •	• • •		682
2760	cr	$C_2H_4 + CR \rightarrow C_2H_2 + H_2 + CR$	• • •			682
2761	cr	$C_2H_4 + CR \to C_2H_4^+ + e^- + CR$				682
2762	cr	$CH_3OH + CR \rightarrow CH_3O^+ + H + e^- + CR$	• • •	• • •		682
2763	cr	$CH_3OH + CR \rightarrow CH_4O^+ + e^- + CR$	• • •	• • •		682
2764	cr	$C_2H_4O + CR \rightarrow CH_3 + CHO + CR$	• • •	• • •		682
2765	cr	$C_2H_4O + CR \rightarrow CH_4 + CO + CR$	• • •	• • •		682
2766	cr	$C_2H_4O + CR \to C_2H_4O^+ + e^- + CR$	• • •			682
2767	cr	$C_2H_5 + CR \rightarrow C_2H_4 + H + CR$	• • •			682
2768	cr	$C_3H_3N + CR \rightarrow C_2H_3 + CN + CR$	• • •			682
2769	cr	$C_3H_4 + CR \rightarrow C_3H_3 + H + CR$	• • •	• • •		682
2770	cr	$C_3H_4 + CR \to C_3H_4^+ + e^- + CR$	• • •			682
2771	cr	$CH_5N + CR \rightarrow HCN + H_2 + H + CR$	• • •			682
2772	cr	$CH^{+} + CR \rightarrow C + H^{+} + CR$	• • •	• • •		682
2773	cr	$Cl + CR \rightarrow Cl^+ + e^- + CR$	• • •			682
2774	cr	$K + CR \rightarrow K^+ + e^- + CR$	• • •	• • •		682
2775	cr	$Na + CR \rightarrow Na^+ + e^- + CR$	• • •	• • •		682
2776	cr	$NaH + CR \rightarrow Na + H + CR$				682
2777	dr	$C_2^+ + e^- \rightarrow C + C$	8.84e-08	-0.50	0	683
2778	dr	$CH^+ + e^- \rightarrow C + H$	7.00e-08	-0.50	0	683
2779	dr	$CN^+ + e^- \rightarrow C + N$	3.38e-07	-0.55	0	683
2780	dr	$CO^+ + e^- \rightarrow O + C$	2.75e-07	-0.55	0	683
2781	dr	$\mathrm{H_2^+} + e^- \rightarrow \mathrm{H} + \mathrm{H}$	2.53e-07	-0.50	0	683
2782	dr	$HeH^+ + e^- \rightarrow H + He$	3.00e-08	-0.50	0	683
2783	dr	$N_2^+ + e^- \rightarrow N + N$	1.80e-07	-0.39	0	683
2784	dr	$HN^+ + e^- \rightarrow N + H$	1.18e-07	-0.50	0	683
2785	dr	$NO^+ + e^- \rightarrow N + O$	4.10e-07	-1.00	0	683
2786	dr	$O_2^+ + e^- \rightarrow O + O$	1.95e-07	-0.70	0	683
2787	dr	$\mathrm{HO^+} + e^- \rightarrow \mathrm{O} + \mathrm{H}$	6.30e-09	-0.48	0	683
2788	$d\mathbf{r}$	$SiH^+ + e^- \rightarrow Si + H$	2.00e-07	-0.50	0	683

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2789	dr	$SiO^+ + e^- \rightarrow Si + O$	2.00e-07	-0.50	0	683
2790	dr	$C_2H^+ + e^- \rightarrow C_2 + H$	1.16e-07	-0.76	0	683
2791	$d\mathbf{r}$	$C_2H^+ + e^- \rightarrow CH + C$	1.05e-07	-0.76	0	683
2792	$\mathrm{d}\mathrm{r}$	$C_2H^+ + e^- \rightarrow C + C + H$	4.80e-08	-0.76	0	683
2793	$\mathrm{d}\mathrm{r}$	$C_2N^+ + e^- \rightarrow C + CN$	1.50e-07	-0.50	0	683
2794	dr	$C_2N^+ + e^- \rightarrow C_2 + N$	1.50e-07	-0.50	0	683
2795	dr	$C_2O^+ + e^- \rightarrow CO + C$	3.00e-07	-0.50	0	683
2796	dr	$\mathrm{CH}_2^+ + e^- \to \mathrm{C} + \mathrm{H}_2$	7.70e-08	-0.60	0	683
2797	dr	$\mathrm{CH}_2^+ + e^- \to \mathrm{CH} + \mathrm{H}$	1.60e-07	-0.60	0	683
2798	dr	$\mathrm{CH}_2^+ + e^- \to \mathrm{C} + \mathrm{H} + \mathrm{H}$	4.00e-07	-0.60	0	683
2799	dr	$SiCH^+ + e^- \rightarrow Si + CH$	1.50e-07	-0.50	0	683
2800	dr	$\mathrm{CO}_2^+ + e^- \to \mathrm{O} + \mathrm{CO}$	4.20e-07	-0.75	0	683
2801	dr	$\mathrm{H_2O^+} + e^- \rightarrow \mathrm{O} + \mathrm{H_2}$	3.90e-08	-0.50	0	683
2802	dr	$\mathrm{H_2O^+} + e^- \rightarrow \mathrm{HO} + \mathrm{H}$	8.60e-08	-0.50	0	683
2803	dr	$\mathrm{H_2O^+} + e^- \rightarrow \mathrm{O} + \mathrm{H} + \mathrm{H}$	3.05e-07	-0.50	0	683
2804	dr	${\rm H_3^+} + e^- \to {\rm H} + {\rm H} + {\rm H}$	4.36e-08	-0.52	0	683
2805	dr	${\rm H_3^+} + e^- \to {\rm H_2} + {\rm H}$	2.34e-08	-0.52	0	683
2806	dr	$\mathrm{CHN^+} + e^- \to \mathrm{CN} + \mathrm{H}$	2.00e-07	-0.50	0	683
2807	dr	$CHO^+ + e^- \rightarrow CO + H$	2.80e-07	-0.69	0	683
2808	$d\mathbf{r}$	$CHN^+ + e^- \rightarrow CN + H$	2.00e-07	-0.50	0	683
2809	dr	$\text{HNO}^+ + e^- \rightarrow \text{NO} + \text{H}$	3.00e-07	-0.50	0	683
2810	dr	$SiHO^+ + e^- \rightarrow Si + HO$	1.50e-07	-0.50	0	683
2811	dr	$SiHO^+ + e^- \rightarrow SiO + H$	1.50e-07	-0.50	0	683
2812	dr	$\mathrm{HN}_2^+ + e^- \rightarrow \mathrm{N}_2 + \mathrm{H}$	9.00e-08	-0.51	0	683
2813	dr	$HN_2^+ + e^- \rightarrow HN + N$	1.00e-08	-0.51	0	683
2814	dr	$\text{CNO}^+ + e^- \rightarrow \text{CO} + \text{N}$	3.00e-07	-0.50	0	683
2815	dr	$H_2N^+ + e^- \rightarrow N + H + H$	2.00e-07	-0.50	0	683
2816	dr	$H_2N^+ + e^- \rightarrow HN + H$	1.00e-07	-0.50	0	683
2817	dr	$NO_2^+ + e^- \rightarrow O + NO$	3.00e-07	-0.50	0	683
2818	dr	$\mathrm{HO}_2^+ + e^- \rightarrow \mathrm{O}_2 + \mathrm{H}$	3.00e-07	-0.50	0	683
2819	dr	$SiH_2^+ + e^- \rightarrow Si + H + H$	2.00e-07	-0.50	0	683
2820	dr	$SiH_2^+ + e^- \rightarrow Si + H_2$	1.50e-07	-0.50	0	683
2821	$\mathrm{d}\mathrm{r}$	$SiH_2^+ + e^- \rightarrow SiH + H$	2.00e-07	-0.50	0	683
2822	$\mathrm{d}\mathrm{r}$	$C_2H_2^+ + e^- \rightarrow C_2H + H$	2.90e-07	-0.50	0	683
2823	$d\mathbf{r}$	$C_2H_2^+ + e^- \to C_2 + H + H$	1.70e-07	-0.50	0	683
2824	dr	$C_2H_2^+ + e^- \rightarrow CH + CH$	7.50e-08	-0.50	0	683
2825	dr	$C_2H_2^+ + e^- \rightarrow CH_2 + C$	2.89e-08	-0.50	0	683
2826	$d\mathbf{r}$	$C_2H_2^+ + e^- \to C_2 + H_2$	1.15e-08	-0.50	0	683
2827	$d\mathbf{r}$	$C_2HO^+ + e^- \rightarrow CO + C + H$	1.50 e-07	-0.50	0	683
2828	$d\mathbf{r}$	$C_2HO^+ + e^- \rightarrow CO + CH$	1.00e-07	-0.50	0	683
2829	$d\mathbf{r}$	$C_2HO^+ + e^- \rightarrow C_2H + O$	1.50e-07	-0.50	0	683

Table 6— Continued

#	Type	Reaction	α	β	γ	Ref
2830	$d\mathbf{r}$	$C_2HO^+ + e^- \rightarrow C_2O + H$	1.00e-07	-0.50	0	683
2831	$d\mathbf{r}$	$C_2N_2^+ + e^- \rightarrow CN + CN$	1.50 e-07	-0.50	0	683
2832	$d\mathbf{r}$	$C_2N_2^+ + e^- \rightarrow CNC + N$	1.50 e-07	-0.50	0	683
2833	$d\mathbf{r}$	$C_2HN^+ + e^- \rightarrow CH + CN$	1.50 e-07	-0.50	0	683
2834	$d\mathbf{r}$	$C_2HN^+ + e^- \rightarrow CNC + H$	1.50 e-07	-0.50	0	683
2835	$\mathrm{d}\mathrm{r}$	$C_3H^+ + e^- \rightarrow C_2H + C$	1.50e-07	-0.50	0	683
2836	$d\mathbf{r}$	$C_3N^+ + e^- \rightarrow C_2 + CN$	3.00e-07	-0.50	0	683
2837	dr	$SiCH_2^+ + e^- \rightarrow Si + CH_2$	2.00e-07	-0.50	0	683
2838	dr	$\mathrm{CH_3^+} + e^- \to \mathrm{H_2} + \mathrm{C} + \mathrm{H}$	3.00e-07	-0.30	0	683
2839	$\mathrm{d}\mathrm{r}$	$\mathrm{CH}_3^+ + e^- \to \mathrm{CH} + \mathrm{H} + \mathrm{H}$	1.60e-07	-0.30	0	683
2840	$\mathrm{d}\mathrm{r}$	$\mathrm{CH}_3^+ + e^- \to \mathrm{CH} + \mathrm{H}_2$	1.40e-07	-0.30	0	683
2841	$\mathrm{d}\mathrm{r}$	$\mathrm{CH_3^+} + e^- \to \mathrm{CH_2} + \mathrm{H}$	4.00e-07	-0.30	0	683
2842	$d\mathbf{r}$	$\mathrm{CH_2O^+} + e^- \to \mathrm{CO} + \mathrm{H} + \mathrm{H}$	5.00e-07	-0.50	0	683
2843	$d\mathbf{r}$	$\mathrm{CH_2O^+} + e^- \to \mathrm{CHO} + \mathrm{H}$	1.00e-07	-0.50	0	683
2844	$d\mathbf{r}$	$\mathrm{H_3O^+} + e^- \rightarrow \mathrm{HO} + \mathrm{H} + \mathrm{H}$	2.60e-07	-0.50	0	683
2845	$d\mathbf{r}$	$\mathrm{H_3O^+} + e^- \rightarrow \mathrm{H_2O} + \mathrm{H}$	1.10e-07	-0.50	0	683
2846	$d\mathbf{r}$	$\mathrm{H_3O^+} + e^- \rightarrow \mathrm{HO} + \mathrm{H_2}$	6.00e-08	-0.50	0	683
2847	$d\mathbf{r}$	$H_3O^+ + e^- \to H_2 + H + O$	5.60e-09	-0.50	0	683
2848	$d\mathbf{r}$	$CHO_2^+ + e^- \to CO + H + O$	8.10e-07	-0.64	0	683
2849	$d\mathbf{r}$	$CHO_2^+ + e^- \rightarrow HO + CO$	3.20e-07	-0.64	0	683
2850	$d\mathbf{r}$	$CHO_2^+ + e^- \to CO_2 + H$	6.00e-08	-0.64	0	683
2851	$d\mathbf{r}$	$\text{CHNO}^+ + e^- \rightarrow \text{CO} + \text{HN}$	3.00e-07	-0.50	0	683
2852	$d\mathbf{r}$	$H_3N^+ + e^- \rightarrow HN + H + H$	1.55e-07	-0.50	0	683
2853	$d\mathbf{r}$	$\mathrm{H_3N^+} + e^- \rightarrow \mathrm{H_2N} + \mathrm{H}$	1.55e-07	-0.50	0	683
2854	$d\mathbf{r}$	$\mathrm{SiC}_2\mathrm{H}^+ + e^- \to \mathrm{C}_2\mathrm{H} + \mathrm{Si}$	1.50e-07	-0.50	0	683
2855	$d\mathbf{r}$	$SiH_3^+ + e^- \rightarrow SiH + H_2$	1.50e-07	-0.50	0	683
2856	dr	$SiH_3^+ + e^- \rightarrow SiH_2 + H$	1.50e-07	-0.50	0	683
2857	$d\mathbf{r}$	$C_2H_2N^+ + e^- \rightarrow CH + HCN$	3.00e-07	-0.50	0	683
2858	$d\mathbf{r}$	$C_2H_2N^+ + e^- \rightarrow CN + CH_2$	3.00e-07	-0.50	0	683
2859	$d\mathbf{r}$	$C_2H_2N^+ + e^- \to C_2N + H_2$	3.00e-07	-0.50	0	683
2860	$d\mathbf{r}$	$C_2H_2O^+ + e^- \to C_2 + H_2O$	2.00e-07	-0.50	0	683
2861	$d\mathbf{r}$	$C_2H_2O^+ + e^- \rightarrow CH_2 + CO$	2.00e-07	-0.50	0	683
2862	$d\mathbf{r}$	$C_2H_2O^+ + e^- \to C_2H_2 + O$	2.00e-07	-0.50	0	683
2863	$d\mathbf{r}$	$C_2H_3^+ + e^- \to C_2H + H + H$	2.95e-07	-0.84	0	683
2864	$d\mathbf{r}$	$C_2H_3^+ + e^- \to C_2H + H_2$	3.00e-08	-0.84	0	683
2865	$d\mathbf{r}$	$C_2H_3^+ + e^- \to C_2H_2 + H$	1.45 e-07	-0.84	0	683
2866	$d\mathbf{r}$	$C_2H_3^+ + e^- \to C_2 + H + H_2$	1.50e-08	-0.84	0	683
2867	$d\mathbf{r}$	$C_2H_3^+ + e^- \rightarrow CH_3 + C$	3.00e-09	-0.84	0	683
2868	$d\mathbf{r}$	$C_2H_3^+ + e^- \rightarrow CH_2 + CH$	1.50e-08	-0.84	0	683
2869	$d\mathbf{r}$	$C_3H_2^+ + e^- \to C_2H_2 + C$	3.00e-08	-0.50	0	683
2870	$d\mathbf{r}$	$C_3HN^+ + e^- \rightarrow C_2 + HCN$	3.00e-07	-0.50	0	683

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2871	$\mathrm{d}\mathrm{r}$	$C_3HN^+ + e^- \rightarrow C_2H + CN$	1.50e-07	-0.50	0	683
2872	$d\mathbf{r}$	$CH_2O_2^+ + e^- \to CO_2 + H + H$	3.00e-07	-0.50	0	683
2873	$d\mathbf{r}$	$CH_4^+ + e^- \rightarrow CH_2 + H + H$	3.00e-07	-0.50	0	683
2874	$d\mathbf{r}$	$\mathrm{CH_4^+} + e^- \to \mathrm{CH_3} + \mathrm{H}$	3.00e-07	-0.50	0	683
2875	$d\mathbf{r}$	$CH_3O^+ + e^- \rightarrow CO + H + H_2$	2.00e-07	-0.50	0	683
2876	$d\mathbf{r}$	$CH_3O^+ + e^- \rightarrow CHO + H + H$	2.00e-07	-0.50	0	683
2877	dr	$CH_3O^+ + e^- \rightarrow CH_2O + H$	2.00e-07	-0.50	0	683
2878	$d\mathbf{r}$	$SiH_3O^+ + e^- \rightarrow SiO + H_2 + H$	1.50e-07	-0.50	0	683
2879	$d\mathbf{r}$	$H_4N^+ + e^- \to H_2N + H + H$	3.20e-07	-0.50	0	683
2880	$d\mathbf{r}$	$H_4N^+ + e^- \to H_2N + H_2$	1.50e-07	-0.50	0	683
2881	$d\mathbf{r}$	$H_4N^+ + e^- \rightarrow H_3N + H$	1.05e-06	-0.50	0	683
2882	dr	$SiH_4^+ + e^- \rightarrow SiH_2 + H_2$	1.50 e-07	-0.50	0	683
2883	$d\mathbf{r}$	$SiH_4^+ + e^- \rightarrow SiH_3 + H$	1.50e-07	-0.50	0	683
2884	$d\mathbf{r}$	$C_2H_3N^+ + e^- \to C_2N + H_2 + H$	2.00e-07	-0.50	0	683
2885	$d\mathbf{r}$	$C_2H_3N^+ + e^- \rightarrow CH_2 + HCN$	3.00e-07	-0.50	0	683
2886	$d\mathbf{r}$	$C_2H_3N^+ + e^- \rightarrow CH_3 + CN$	2.00e-07	-0.50	0	683
2887	$d\mathbf{r}$	$C_2H_3O^+ + e^- \rightarrow CH_3 + CO$	1.50e-07	-0.50	0	683
2888	$d\mathbf{r}$	$C_2H_3O^+ + e^- \to C_2H_2O + H$	1.50e-07	-0.50	0	683
2889	$d\mathbf{r}$	$C_2H_4^+ + e^- \to C_2H_2 + H + H$	3.70e-07	-0.76	0	683
2890	$d\mathbf{r}$	$C_2H_4^+ + e^- \to C_2H_2 + H_2$	3.36e-08	-0.76	0	683
2891	$d\mathbf{r}$	$C_2H_4^+ + e^- \to C_2H_3 + H$	6.16e-08	-0.76	0	683
2892	$d\mathbf{r}$	$C_2H_4^+ + e^- \to C_2H + H_2 + H$	5.60e-08	-0.76	0	683
2893	$d\mathbf{r}$	$C_2H_4^+ + e^- \rightarrow CH_4 + C$	5.60e-09	-0.76	0	683
2894	dr	$C_2H_4^+ + e^- \rightarrow CH_3 + CH$	1.12e-08	-0.76	0	683
2895	$d\mathbf{r}$	$C_2H_4^+ + e^- \rightarrow CH_2 + CH_2$	2.24e-08	-0.76	0	683
2896	$d\mathbf{r}$	$C_3H_2N^+ + e^- \rightarrow C_2H + HNC$	7.50e-08	-0.50	0	683
2897	$d\mathbf{r}$	$C_3H_2N^+ + e^- \rightarrow HC_3N + H$	1.50e-07	-0.50	0	683
2898	$d\mathbf{r}$	$C_3H_3^+ + e^- \rightarrow C_2H_2 + CH$	6.99 e-08	-0.50	0	683
2899	$d\mathbf{r}$	$CH_3O_2^+ + e^- \to CO_2 + H_2 + H$	1.50e-07	-0.50	0	683
2900	$d\mathbf{r}$	$\mathrm{CH_3O_2^+} + e^- \to \mathrm{CH_2O_2} + \mathrm{H}$	1.50e-07	-0.50	0	683
2901	$d\mathbf{r}$	$CH_4N^+ + e^- \to CN + H_2 + H_2$	3.00e-08	-0.50	0	683
2902	$d\mathbf{r}$	$\mathrm{CH_4N^+} + e^- \rightarrow \mathrm{CH_2} + \mathrm{H_2N}$	1.50 e-07	-0.50	0	683
2903	$d\mathbf{r}$	$CH_4N^+ + e^- \rightarrow HCN + H + H_2$	3.00e-07	-0.50	0	683
2904	$d\mathbf{r}$	$\mathrm{CH_4N^+} + e^- \to \mathrm{CH_3N} + \mathrm{H}$	1.50e-07	-0.50	0	683
2905	$d\mathbf{r}$	$\mathrm{CH_4O^+} + e^- \to \mathrm{CH_3} + \mathrm{HO}$	3.00e-07	-0.50	0	683
2906	$d\mathbf{r}$	$\mathrm{CH_4O^+} + e^- \rightarrow \mathrm{CH_2O} + \mathrm{H_2}$	3.00e-07	-0.50	0	683
2907	$d\mathbf{r}$	$CH_5^+ + e^- \rightarrow CH_3 + H_2$	1.40e-08	-0.52	0	683
2908	$d\mathbf{r}$	$\mathrm{CH}_5^+ + e^- \to \mathrm{CH}_4 + \mathrm{H}$	1.40e-08	-0.52	0	683
2909	$d\mathbf{r}$	$\mathrm{CH}_5^+ + e^- \to \mathrm{CH}_3 + \mathrm{H} + \mathrm{H}$	1.95 e-07	-0.52	0	683
2910	$d\mathbf{r}$	$CH_5^+ + e^- \to CH_2 + H_2 + H$	4.80e-08	-0.52	0	683
2911	$d\mathbf{r}$	$CH_5^+ + e^- \to CH + H_2 + H_2$	3.00e-09	-0.52	0	683

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2912	dr	$SiH_5^+ + e^- \rightarrow SiH_3 + H_2$	1.50e-07	-0.50	0	683
2913	dr	$SiH_5^+ + e^- \rightarrow SiH_4 + H$	1.50e-07	-0.50	0	683
2914	$d\mathbf{r}$	$C_2H_4N^+ + e^- \rightarrow CH_2CN + H + H$	1.50e-07	-0.50	0	683
2915	$d\mathbf{r}$	$C_2H_4N^+ + e^- \to C_2H_3N + H$	1.50e-07	-0.50	0	683
2916	dr	$C_2H_4O^+ + e^- \rightarrow CH_3 + CHO$	1.50 e-07	-0.50	0	683
2917	dr	$C_2H_4O^+ + e^- \to C_2H_2O + H + H$	1.50 e-07	-0.50	0	683
2918	$d\mathbf{r}$	$C_2H_4O^+ + e^- \to C_2H_2O + H_2$	1.50 e-07	-0.50	0	683
2919	dr	$C_2H_5^+ + e^- \to C_2H + H_2 + H_2$	1.50 e-07	-0.50	0	683
2920	$d\mathbf{r}$	$C_2H_5^+ + e^- \to C_2H_2 + H_2 + H$	3.00e-07	-0.50	0	683
2921	$d\mathbf{r}$	$C_2H_5^+ + e^- \to C_2H_3 + H_2$	1.50 e-07	-0.50	0	683
2922	$d\mathbf{r}$	$C_2H_5^+ + e^- \to C_2H_4 + H$	1.50 e-07	-0.50	0	683
2923	$d\mathbf{r}$	$C_3H_4^+ + e^- \to C_3H_3 + H$	2.57e-06	-0.67	0	683
2924	$d\mathbf{r}$	$C_3H_4^{+} + e^{-} \rightarrow C_2H_3 + CH$	2.95e-08	-0.67	0	683
2925	$d\mathbf{r}$	$C_3H_4^+ + e^- \to C_2H_2 + CH_2$	1.77e-07	-0.67	0	683
2926	$d\mathbf{r}$	$C_3H_4^{+} + e^{-} \rightarrow C_2H + CH_3$	2.95 e-08	-0.67	0	683
2927	$d\mathbf{r}$	$\mathrm{CH_5N^+} + e^- \rightarrow \mathrm{CH_3} + \mathrm{H_2N}$	1.50 e-07	-0.50	0	683
2928	dr	$\mathrm{CH_5N^+} + e^- \rightarrow \mathrm{CH_3N} + \mathrm{H_2}$	1.50 e-07	-0.50	0	683
2929	$d\mathbf{r}$	$\mathrm{CH_5O^+} + e^- \rightarrow \mathrm{CH_2O} + \mathrm{H_2} + \mathrm{H}$	9.10e-08	-0.67	0	683
2930	$d\mathbf{r}$	$\mathrm{CH_5O^+} + e^- \rightarrow \mathrm{CH_3} + \mathrm{H_2O}$	8.19e-08	-0.67	0	683
2931	$d\mathbf{r}$	$\mathrm{CH_5O^+} + e^- \rightarrow \mathrm{CH_3} + \mathrm{HO} + \mathrm{H}$	4.64e-07	-0.67	0	683
2932	$d\mathbf{r}$	$CH_5O^+ + e^- \to CH_2 + H_2O + H$	1.91e-07	-0.67	0	683
2933	dr	$\mathrm{CH_5O^+} + e^- \rightarrow \mathrm{CH_3OH} + \mathrm{H}$	2.73e-08	-0.67	0	683
2934	dr	$C_4H_2N^+ + e^- \rightarrow HC_3N + CH$	3.00e-07	-0.50	0	683
2935	$\mathrm{d}\mathrm{r}$	$C_2H_5O^+ + e^- \rightarrow CH_2O + CH_3$	1.50e-07	-0.50	0	683
2936	dr	$C_2H_5O^+ + e^- \to C_2H_2O + H_2 + H$	1.50e-07	-0.50	0	683
2937	$d\mathbf{r}$	$C_2H_5O^+ + e^- \rightarrow CH_4 + CO + H$	3.00e-07	-0.50	0	683
2938	$d\mathbf{r}$	$C_2H_5O^+ + e^- \to C_2H_4O + H$	1.50e-07	-0.50	0	683
2939	$d\mathbf{r}$	$C_2H_6^+ + e^- \to C_2H_4 + H_2$	1.50e-07	-0.50	0	683
2940	dr	$C_2H_6^+ + e^- \to C_2H_5 + H$	1.50e-07	-0.50	0	683
2941	$d\mathbf{r}$	$C_3H_5^+ + e^- \to C_3H_3 + H_2$	1.50e-07	-0.50	0	683
2942	$d\mathbf{r}$	$C_3H_5^+ + e^- \to C_3H_4 + H$	1.50e-07	-0.50	0	683
2943	dr	$C_4H_4^+ + e^- \to C_4H_3 + H$	3.30e-07	-0.50	0	683
2944	$\mathrm{d}\mathrm{r}$	$CH_6N^+ + e^- \to CH_3N + H_2 + H$	1.50e-07	-0.50	0	683
2945	$d\mathbf{r}$	$\mathrm{CH_6N^+} + e^- \rightarrow \mathrm{CH_5N} + \mathrm{H}$	1.50e-07	-0.50	0	683
2946	dr	$C_2H_6O^+ + e^- \to C_2H_2O + H_2 + H_2$	1.50e-07	-0.50	0	683
2947	$d\mathbf{r}$	$C_2H_6O^+ + e^- \rightarrow CH_4 + CH_2O$	1.50e-07	-0.50	0	683
2948	$d\mathbf{r}$	$C_2H_6O^+ + e^- \to C_2H_4O + H_2$	1.50e-07	-0.50	0	683
2949	$d\mathbf{r}$	$C_2H_6O^+ + e^- \to C_2H_5 + HO$	1.50e-07	-0.50	0	683
2950	$d\mathbf{r}$	$C_2H_7O^+ + e^- \to C_2H_4 + H_2O + H$	1.50e-07	-0.50	0	683
2951	$d\mathbf{r}$	$C_2H_7O^+ + e^- \to C_2H_4O + H_2 + H$	1.50e-07	-0.50	0	683
2952	$d\mathbf{r}$	$C_2H_7O^+ + e^- \rightarrow C_2H_5OH + H$	1.50e-07	-0.50	0	683

Table 6—Continued

#	Type	Reaction	α	β	γ	Ref
2953	$d\mathbf{r}$	$C_3H_6O^+ + e^- \to CH_3 + CH_3 + CO$	1.50e-07	-0.50	0	683
2954	$d\mathbf{r}$	$C_3H_6O^+ + e^- \to C_2H_4O + CH_2$	1.50 e-07	-0.50	0	683
2955	$d\mathbf{r}$	$C_3H_7O^+ + e^- \to C_2H_4O + CH_3$	1.50 e-07	-0.50	0	683
2956	$d\mathbf{r}$	$C_4H_7^+ + e^- \to C_3H_3 + CH_4$	1.95 e-07	-0.50	0	683
2957	$d\mathbf{r}$	$C_4H_7^+ + e^- \to C_2H_3 + C_2H_4$	2.25 e-08	-0.50	0	683
2958	$d\mathbf{r}$	$C_4H_7^+ + e^- \to C_2H_2 + C_2H_5$	2.25 e-08	-0.50	0	683
2959	$d\mathbf{r}$	$C_2H_6NO_2^+ + e^- \to C_2H_5NO_2 + H$	2.34e-08	-0.52	0	683
2960	$d\mathbf{r}$	$C_2H_7^+ + e^- \to C_2H_5 + H_2$	1.50 e-07	-0.50	0	683
2961	dr	$C_2H_7^+ + e^- \to C_2H_6 + H$	1.50 e-07	-0.50	0	683
2962	$d\mathbf{r}$	$C_3H_6^+ + e^- \to C_3H_3 + H_2 + H$	1.50 e-07	-0.50	0	683
2963	dr	$C_3H_6^+ + e^- \to C_3H_4 + H_2$	1.50 e-07	-0.50	0	683
2964	$d\mathbf{r}$	$C_3H_7^+ + e^- \rightarrow C_2H_2 + CH_3 + H_2$	2.53e-08	-0.73	0	683
2965	$d\mathbf{r}$	$C_3H_7^+ + e^- \to C_2H_3 + CH_3 + H$	4.37e-08	-0.73	0	683
2966	dr	$C_3H_7^+ + e^- \to C_2H_4 + CH_2 + H$	9.20e-09	-0.73	0	683
2967	dr	$C_3H_7^+ + e^- \to C_3H_4 + H_2 + H$	6.60 e-08	-0.73	0	683
2968	$d\mathbf{r}$	$C_3H_7^+ + e^- \to C_2H_6 + CH$	1.50 e-07	-0.73	0	683
2969	$d\mathbf{r}$	$C_4H_2^+ + e^- \to C_2H + C_2H$	2.75 e-07	-0.79	0	683
2970	$d\mathbf{r}$	$C_4H_2^+ + e^- \to C_4H + H$	8.25 e-07	-0.79	0	683
2971	$d\mathbf{r}$	$C_3H_8^+ + e^- \to C_2H_6 + CH_2$	1.50 e-07	-0.50	0	683
2972	$d\mathbf{r}$	$C_3H_9^+ + e^- \to C_2H_6 + CH_3$	1.50 e-07	-0.50	0	683
2973	dr	$C_4H_9^+ + e^- \to C_2H_6 + C_2H_3$	1.50 e-07	-0.50	0	683
2974	ra	$H + CH_3 \rightarrow CH_4 + \gamma$	1.31e-16	-1.29	20	31
2975	ra	$H + C_2H_4 \rightarrow C_2H_5 + \gamma$	4.46e-17	-0.53	19	31
2976	ra	$H + C_4H_2 \rightarrow C_4H_3 + \gamma$	5.64e-13	2.75	50	31
2977	ra	$H + C_4H_3 \rightarrow C_4H_4 + \gamma$	6.22e-12	-3.01	162	31
2978	ra	$CH_3 + CH_3 \rightarrow C_2H_6 + \gamma$	2.96e-14	-3.23	75	31
2979	ra	$\mathrm{H^+} + e^- \rightarrow \mathrm{H} + \gamma$	3.50 e-12	-0.75	0	689
2980	ra	$\mathrm{He^+}+\ e^- \to \mathrm{He} + \gamma$	5.36e-12	-0.50	0	690

^{*}Consult Section 2.3 on how the reaction barrier is calculated.

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Å: Verner et al. 1993; Verner & Yakovlev 1995; Verner et al. 1996, 256.8 Å - 851.3 $ilde{A}$: Badnell et al. 2005; (644) 0.1 $ilde{A}$ – 230 $ilde{A}$: Verner et al. 1993; Verner & Yakovlev 1995; Verner et al. 1996, 235.9 Å - 910.44 Å: Badnell et al. 2005; (645) 1 Å - 130 Å: Barfield et al. 1972, 130 Å – 200 Å: Henry 1970, 227.3 Å – 790.1 Å: Badnell et al. 2005; (646) 180 Å - 16640 Å: Geltman 1962; Broad & Reinhardt 1976; (647) 0.6 Å − 918 Å: Barfield et al. 1972; Padial et al. 1985, 918 Å − 1210 Å: Pouilly et al. 1983; Padial et al. 1985; (648) 12 Å – 617 Å: Walker & Kelly 1972, 827 Å – 1170 Å: Barsuhn & Nesbet 1978; van Dishoeck 1987, 1200 Å - 3589.9 Å: van Dishoeck 1987, branching ratio: Barsuhn & Nesbet 1978; (649) 0.61 Å - 626.8 Å: Barfield et al. 1972, 905.8 Å - 1108 Å: Lavendy et al. 1984, 1987; (650) 89.6 Å - 564.5 Å: Masuoka & Samson 1981, 584.3 Å – 835.29 Å: Cairns & Samson 1965; Kronebusch & Berkowitz 1976; (651) 89.6 Å – 584 Å: Masuoka & Samson 1981; Kronebusch & Berkowitz 1976; (652) 0 Å – 1117.8 Å: McElroy & McConnell 1971; (653) 1 Å – 200 Å: $\sigma(H_2) \approx 2\sigma(H)$, 209.3 Å - 500 Å: Samson & Cairns 1965; Browning & Fryar 1973, 500 Å - 844 Å: Cook & Metzger 1964; Browning & Fryar 1973; (654) 9.9 Å – 247.2 Å: Huffman 1969, 303.8 Å – 1037 Å: Samson & Cairns 1965; Cook & Metzger 1964; Huffman et al. 1963; Kronebusch & Berkowitz 1976; (655) 1 Å – 180 Å: Huebner & Mukherjee 2015, 180 Å – 580 Å: Lee et al. 1973; Kronebusch & Berkowitz 1976, 580 Å - 1350 Å: Watanabe et al. 1967; Kronebusch & Berkowitz 1976, 1350 Å – 1910 Å: Marmo 1953; (656) 1 Å – 1771.2 Å: Barfield et al. 1972; Brion et al. 1979, 1771.2 Å – 2000 Å: Ackerman 1971, 2000 Å – 2200 Å: Herman & Mentall 1982, 2250 Å – 2423.7 Å: Shardanand & Rao 1977, branching ratio: Huffman 1969; Samson & Cairns 1964; Matsunaga & Watanabe 1967; Brion et al. 1979; (657) Experimental 0.61 Å - 625.8 Å: Barfield et al. 1972, 1150 Å - 1830 Å: Nee & Lee 1984, Theoretical: Van Dishoeck 1984; (658) 2 Å – 270 Å: Henry & McElroy 1968, 303.78 Å – 555.26 Å: Cairns & Samson 1965, 580 Å – 1670 Å: Nakata et al. 1965, branching ratio: Kronebusch & Berkowitz 1976; Nakata et al. 1965; (659) 1 Å - 100 Å: Barfield et al. 1972, 180 Å - 700 Å: Phillips et al. 1977; Dibeler et al. 1966, 700 Å - 980.8 Å: Phillips et al. 1977; Katayama et al. 1973; Watanabe & Jursa 1964, 980.8 Å – 1860 Å: Watanabe & Jursa 1964; Watanabe & Zelikoff 1953, branching ratio: McNesby et al. 1962; Slanger & Black 1982; Kronebusch & Berkowitz 1976; (660) 1 Å – 1950 Å: Huebner & Mukherjee 2015; (661) 1 Å – 1850 Å: Huebner & Mukherjee 2015; $(662)\ 0.61\ \text{Å} - 625\ \text{Å}$: Huebner & Mukherjee 2015; Barfield et al. 1972, 1080 Å - 1700 Å: Zelikoff et al. 1953, 1730 Å – 2400 Å: Selwyn et al. 1977, branching ratio: Okabe et al. 1978; (663) 1 Å - 840 Å: $\sigma(H_2N) \approx 2\sigma(H) + \sigma(N)$, 1250 Å - 1970 Å: Saxon et al. 1983; (664) 0.6 Å – 940 Å: Huebner & Mukherjee 2015, 1080 Å – 1800 Å: Nakayama et al. 1959, 1850 Å – 3978 Å: Bass et al. 1976, branching ratio: Nakayama et al. 1959; (665) $0.6 \text{ Å} - 742 \text{ Å}: \sigma(O_3) \approx 3\sigma(O), 1060 \text{ Å} - 1360 \text{ Å}: Tanaka et al. 1953, 1365 \text{ Å} -$ 2000 Å: Ackerman 1971, 2975 Å - 3300 Å: Moortgat & Warneck 1975, 3300 Å -8500 Å: Griggs 1968; (666) 600 Å - 1000 Å: Metzger & Cook 1964, 1050 Å - 2011 A: Nakayama & Watanabe 1964, branching ratio: Schoen 1962; Okabe 1981, 1983; (667) 0 Å -500 Å: Barfield et al. 1972, 600 Å -1760 Å: Mentall et al. 1971, 1760 Å - 1850 Å: Gentieu & Mentall 1970, 2000 Å - 2634.7 Å: Calvert & Pitts 1966, 2635.7 $Å - 3531.7 \ Å$: Rogers 1990, 3531.7 $Å - 3740 \ Å$: Calvert & Pitts 1966, branching ratio: Clark et al. 1978; Mentall et al. 1971; Guyon et al. 1976; (668) 0.61 Å - 627 Å: Barfield et al. 1972, 1200 Å - 2000 Å: Okabe 1970, 2100 Å - 2550 Å: Dixon & Kirby 1968; (669) 0.6 Å – 940 Å: Barfield et al. 1972, 2000 Å – 4000 Å: Cox & Derwent 1977, 3120 Å - 3900 Å: Stockwell & Calvert 1978; (670) 1 Å - 350 Å: Huebner & Mukherjee 2015, 374.1 Å – 1650 Å: Sun & Weissler 1955; Watanabe & Sood 1965, 1650 Å – 2170 Å: Watanabe 1954, 2140 Å – 2330 Å: Thompson et al. 1963, branching ratio: McNesby et al. 1962; Schurath et al. 1969; Kronebusch & Berkowitz 1976; (671) 0.6 Å

-630 Å: Huebner & Mukherjee 2015, 915 Å -3980 Å: $\sigma(NO_3) \approx \sigma(NO_2)$, 4000 Å - 7030 Å: Graham & Johnston 1978b, branching ratio: Magnotta & Johnston 1980; (672) 23.6 Å - 1370 Å: Lukirskii et al. 1964; Rustgi 1964; Ditchburn 1955, 1380 Å -1600 Å: Mount & Moos 1978, branching ratio: Gorden & Ausloos 1967; Calvert & Pitts 1966; Stief et al. 1972; Slanger & Black 1982; Kronebusch & Berkowitz 1976; (673) 1 A - 1100 A: Huebner & Mukherjee 2015, branching ratio: Gorden & Ausloos 1961; Huebner & Mukherjee 2015; (674) 0 Å – 1100 Å: $\sigma(\text{HNO}_3) \approx \sigma(\text{NO}_3)$, 1100 Å – 1900Å: Okabe 1980, 1900 Å – 3300Å: Molina & Molina 1981; (675) 1 Å – 100 Å: $\sigma(C_2H_4) \approx 2\sigma(C) + 4\sigma(H)$, 180 Å – 1065 Å: Lee et al. 1973; Schoen 1962, 1065 Å – 1960 Å: Schoen 1962; Zelikoff et al. 1953, branching ratio: Lee et al. 1973; McNesby & Okabe 1964; Back & Griffiths 1967; (676) 0.61 Å - 250 Å: $\sigma(C_2H_4) \approx 2\sigma(C) + 6\sigma(H)$, 354 Ä – 1127 Ä: Koch & Skibowski 1971, 1160 Ä – 1200 Ä: Lombos et al. 1967, 1200 Ä – 1380 Å: Okabe & Becker 1963, 1380 Å – 1600 Å: Mount & Moos 1978, branching ratio: Lias et al. 1970; Huebner & Mukherjee 2015; (677) 2000 Å – 3450 Å: Baulch et al. 1982, branching ratio: Weaver et al. 1977; (678) 1200 Å – 2053 Å: Salahub & Sandorfy 1971, branching ratio: Porter & Noyes 1959; Huebner & Mukherjee 2015; (679) 0.1 Å - 2412.63 A: Verner et al. 1993; Verner & Yakovley 1995; Verner et al. 1996; (680) 0.1 A – 2856.34 Ä: Verner et al. 1993; Verner & Yakovlev 1995; Verner et al. 1996; (681) 0.61 Å – 877.46 Å: Barfield et al. 1972, 1050 Å - 1350 Å: Myer & Samson 1970, 1400 Å - 2200 Å: Inn 1975; (682) Harada et al. 2010; Rimmer & Helling 2013; (683) Harada et al. 2010; (684) 1 Å - 3000 Å: $\sigma(N_2O_3) \approx \sigma(NO_2) + \sigma(NO)$, 3000 Å - 4000 Å: Stockwell & Calvert 1978; (685) Pitts et al. 1982; (686) Vakhtin et al. 2001; (687) Fahr & Nayak 1994; Ferradaz et al. 2009; Friedrichs et al. 2002; Okabe 1981; (688) Fahr & Nayak 1996; (689) Prasad & Huntress 1980; (690) Ercolano & Storey 2006.