

Quasiclassical Rate Coefficients for the H₂+H₂ Reaction and Dissociation

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Vibrational state-to-state quasiclassical rate coefficients of the H₂+H₂ reaction summed over product rotational states for thermalized reactants' rotations and translations are given at various values of the temperature in the range 1000–4000 K. Values are given for both reactive and nonreactive processes. Separate values are also given for processes involving dissociation. © 2002 American Institute of Physics.

Key words: collision-induced dissociation; H₂+H₂ reaction; quasiclassical trajectories; state-to-state rate coefficients; vibrational deactivation.

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1. Introduction

The accurate calculation of both state-to-state and dissociation rate coefficients is of key importance for the modeling of systems of practical relevance. In the case of the $H_2 + H_2$ system, knowledge of the detailed rate coefficients is relevant to the modeling of nonequilibrium systems of interest for astrophysical,¹ combustion,² and spacecraft³ applications as well as for the production of light negative ions.⁴

Presently, a full dimensional quantum mechanical calculation of the rate coefficients of $H_2 + H_2$ is impractical due to

the high barrier to reaction (the barrier energy is larger than the H_2 dissociation energy). For this reason, up to now, only a reduced dimensionality quantum calculation has been performed⁵ for a limited range of energies.

On the contrary, full dimensional quasiclassical trajectory (QCT)⁶ calculations can be more easily performed to provide *a priori* estimates of the rate coefficients for a wide range of energetic conditions. As a matter of fact, recently, some full dimension QCT calculations for $H_2 + H_2$ have been reported in the literature.^{1,7-9} The thermal collision induced dissociation rate coefficients of $H_2 + H_2$ (with one of the two hydrogen molecules in its ground state) were discussed by Martin *et al.*¹ The effect of the initial vibration, rotation and translation on the amount of collisional energy transferred during the process was also evaluated at the total energies of 259–656 J/mol (though limited to small values of the impact parameter) by Mandy *et al.*⁷ We have already discussed the QCT estimates of the reactive properties of the $H_2 + H_2$ collisions in two papers by Ceballos *et al.*^{8,9} In the first of them,⁸ results from some full dimensional QCT calculations were compared with model (reduced dimensionality) quantum and QCT results in order to investigate the validity of the model as well as the mechanisms of the exchange and dissociative processes. In the more recent study,⁹ instead, full dimensional QCT calculations were performed for a wider range of energies to allow an investigation of the dependence of the detailed rate coefficients on both the initial vibrational energy and the temperature. In the present paper, tables of related vibrational state-to-state rate coefficients calculated for a fairly wide range of temperatures are presented.

The QCT calculations were performed using the potential energy surface fitted by Paniagua and co-workers¹⁰ to an extended set of accurate potential energy values.¹¹ The Paniagua's surface exhibits a collinear transition state with the two inner H atoms being separated by 0.748 Å and the two outer atoms being separated by 4.141 Å. The transition state has an energy 464.8 J/mol higher than the $H_2 + H_2$ asymptotic minimum and 6.7 J/mol higher than the H_2 dissociation limit.

2. The Quasiclassical Calculations

The collision between two hydrogen molecules (denoted by H_1-H_2 and H_3-H_4) in specific vibrotational states (denoted by v_{1-2} , j_{1-2} and v_{3-4} , j_{3-4} for the first and the second reactant molecule, respectively) can lead to several kinds of elementary processes. These processes can be non-reactive, when the identity of both reactant molecules is preserved, or reactive, when the identity of reactant molecules is not preserved since the old bonds break and one or two new ones are formed. Obviously, in both nonreactive and reactive processes, the final vibrotational molecular states can differ from the initial ones. Other elementary processes occurring when two hydrogen molecules collide are the dissociation processes. In this case, one or both reactant bonds are broken and atomic hydrogen is produced. Dissociation processes can accompany both nonreactive and reactive processes. We consider in the present work, the rate coefficients for reactive

and nonreactive processes (including dissociation) starting from reactants in a given pair of vibrational states and ending with products in a given pair of vibrational states.

Although quasiclassical approaches are conceptually simple, the computational task associated with the calculation of vibrational state-specific (from a given pair of reactant vibrational states v_{1-2} and v_{3-4} to a given product vibrational state v' of either product molecules) rate coefficients at different temperatures of the system is not a trivial computational task. In fact, in a quasiclassical approach these quantities are formulated as:

$$k_{v_{1-2},v_{3-4} \rightarrow v'}(T) = \frac{\sum_{j_{1-2}} g(2j_{1-2}+1) e^{-\epsilon_{j_{1-2}}/k_B T}}{Q_{R_{1-2}}} \times \frac{\sum_{j_{3-4}} g(2j_{3-4}+1) e^{-\epsilon_{j_{3-4}}/k_B T}}{Q_{R_{3-4}}} \times \left(\frac{8}{k_B^3 T^3 \pi \mu} \right)^{1/2} \int_0^\infty dE_{tr} E_{tr} e^{-E_{tr}/k_B T_{tr}} \times \sigma_{v_{1-2},v_{3-4} \rightarrow v'}(E_{tr}), \quad (1)$$

where g is 1 for even and 3 for odd rotational H₂ levels, μ is the reduced mass of H₂-H₂, k_B is the Boltzmann's constant, $Q_{R_{1-2}}$ and $Q_{R_{3-4}}$ are the H₂ rotational partition functions for the initial H₁-H₂ and H₃-H₄ molecules, $\epsilon_{j_{1-2}}$ and $\epsilon_{j_{3-4}}$ are the energies of the j th rotational initial state for the H₁-H₂ and H₃-H₄ molecules, E_{tr} is the translational energy, and $\sigma_{v_{1-2},v_{3-4} \rightarrow v'}$ is the degeneracy averaged detailed cross section $\sigma_{v_{1-2},v_{3-4} \rightarrow v',j'}$ summed over the product rotational states j' .

In a similar way, the rate coefficients from a given pair of reactant vibrational states v_{1-2} and v_{3-4} to dissociation (denoted by d) at the temperature T are formulated as:

$$k_{v_{1-2},v_{3-4} \rightarrow d}(T) = \frac{\sum_{j_{1-2}} g(2j_{1-2}+1) e^{-\epsilon_{j_{1-2}}/k_B T}}{Q_{R_{1-2}}} \times \frac{\sum_{j_{3-4}} g(2j_{3-4}+1) e^{-\epsilon_{j_{3-4}}/k_B T}}{Q_{R_{3-4}}} \times \left(\frac{8}{k_B^3 T^3 \pi \mu} \right)^{1/2} \int_0^\infty dE_{tr} E_{tr} e^{-E_{tr}/k_B T_{tr}} \times \sigma_{v_{1-2},v_{3-4} \rightarrow d}(E_{tr}), \quad (2)$$

where $\sigma_{v_{1-2},v_{3-4} \rightarrow d}(E_{tr})$ is the degeneracy averaged detailed dissociative cross section.

In a Monte Carlo approach the QCT detailed cross section $\sigma_{v_{1-2},v_{3-4} \rightarrow v'}(E_{tr})$ can be approximated as:

$$\sigma_{v_{1-2},v_{3-4} \rightarrow v'}(E_{tr}) = \pi b_{\max}^2 \frac{N_{v_{1-2},v_{3-4} \rightarrow v'}^P(E_{tr})}{2N_{v_{1-2},v_{3-4}}(E_{tr})}, \quad (3)$$

where b_{\max} is the maximum value of the impact parameter at which the process can still occur. $N_{v_{1-2},v_{3-4}}(E_{tr})$ is the total

number of trajectories integrated from the v_{1-2} and v_{3-4} pair of initial vibrational states at the collision energy E_{tr} considered. $N_{v_{1-2},v_{3-4} \rightarrow v'}^P(E_{tr})/2N_{v_{1-2},v_{3-4}}(E_{tr})$ is the fraction of the $N_{v_{1-2},v_{3-4}}(E_{tr})$ events that follow process P and form a product molecule in the vibrational state v' . The process P can be either nonreactive or reactive. In particular, the events contributing to the nonreactive cross section are all the collisions leading to a final product vibrational state v' of either the H₁-H₂ or the H₃-H₄ reactant molecule eventually accompanied (or not accompanied) by dissociation of one of the two molecules. Events contributing to the reactive cross sections are collisions leading to the final vibrational state v' of one of the possible H₁-H₃, H₁-H₄, H₂-H₃, or H₂-H₄ product molecule formed in the process eventually accompanied (or not accompanied) by dissociation.

The fully dissociative cross section is given in a QCT Monte Carlo approach by:

$$\sigma_{v_{1-2},v_{3-4} \rightarrow d}(E_{tr}) = \pi b_{\max}^2 \frac{N_{v_{1-2},v_{3-4} \rightarrow d}^d(E_{tr})}{2N_{v_{1-2},v_{3-4}}(E_{tr})}, \quad (4)$$

where $N_{v_{1-2},v_{3-4} \rightarrow d}^d(E_{tr})/2N_{v_{1-2},v_{3-4}}(E_{tr})$ is the fraction of $N_{v_{1-2},v_{3-4}}(E_{tr})$ leading to full dissociation into four atoms.

In Eqs. (3) and (4), the factor 2 is introduced to take into account the fact that the result of one collision (trajectory) can be two molecules or, in general, two events, (formation of one molecule and dissociation of an initial molecule or dissociation of the two initial molecules).

QCT calculations were performed using the VENUS96 program.¹² For the reactants all the 15 possible combinations of the vibrational quantum numbers 5, 7, 9, 11, and 13 were considered. The translational and rotational energies were selected according to the Boltzmann's distribution for $T = T_{\text{rot}} = T_{tr} = 1000, 2000, \text{ and } 4000 \text{ K}$. The maximum impact parameter b_{\max} was selected appropriately for each set of energetical conditions in order to converge all types of processes (with the exception, as usual, of the elastic ones). For a given set of initial conditions the number of integrated trajectories ranges from 110 250 (at high vibrational states and temperatures) to 600 000 (at low vibrational states and temperatures). The overall number of integrated trajectories exceeds 10 000 000.

Trajectories are stopped when at least four of the six internuclear distances exceed the value of 8 Å. At this point the internal (kinetic and potential) energies are calculated for each pair of atoms. A pair of atoms is considered as bound when its internal energy is smaller than the dissociation limit. Related rotational and vibrational quantum numbers are then determined by applying the popular discretization recipe of Truhlar and Muckerman:⁶ (1) the rotational angular momentum and the related rotational number are calculated at first; (2) then the vibrational number is calculated using a semi-classical method, i.e., by equating the integral of the molecular momentum between the classical turning points to

TABLE 1. Vibrational state-to-state nonreactive $\text{H}_1\text{-H}_2(v_{1-2}=5) + \text{H}_3\text{-H}_4(v_{3-4})$ rate coefficients at $T=1000$ K ($\text{H}_2 + \text{H}_2$ nonreactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.621(-12)	5.6	.295(-11)	3.1	.606(-11)	2.1	.661(-11)	2.6	.711(-11)	2.4
1	.135(-11)	3.8	.324(-11)	3.0	.623(-11)	2.1	.664(-11)	2.6	.741(-11)	2.4
2	.192(-11)	3.2	.418(-11)	2.6	.689(-11)	2.0	.729(-11)	2.5	.822(-11)	2.2
3	.652(-11)	1.7	.762(-11)	1.9	.845(-11)	1.8	.907(-11)	2.2	.103(-10)	2.0
4	.199(-09)	0.3	.382(-10)	0.9	.362(-10)	0.9	.208(-10)	1.5	.154(-10)	1.6
5	.187(-08)	0.0	.106(-08)	0.1	.101(-08)	0.1	.102(-08)	0.2	.192(-08)	0.1
6	.203(-09)	0.3	.377(-10)	0.9	.497(-10)	0.7	.162(-10)	1.7	.645(-11)	2.5
7	.657(-11)	1.7	.106(-08)	0.1	.884(-11)	1.8	.527(-11)	3.0	.236(-11)	4.2
8	.147(-11)	3.6	.426(-10)	0.8	.744(-10)	0.6	.554(-11)	2.9	.250(-11)	4.1
9	.696(-12)	5.2	.612(-11)	2.2	.959(-09)	0.1	.101(-10)	2.1	.306(-11)	3.7
10	.393(-12)	7.0	.210(-11)	3.7	.569(-10)	0.7	.554(-10)	0.9	.559(-11)	2.7
11	.216(-12)	9.4	.125(-11)	4.8	.552(-11)	2.2	.927(-09)	0.2	.160(-10)	1.6
12	.786(-13)	15.6	.547(-12)	7.3	.156(-11)	4.2	.519(-10)	0.9	.741(-10)	0.7
13	.326(-13)	24.3	.190(-12)	12.3	.553(-12)	7.0	.433(-11)	3.3	.161(-08)	0.1
14			.403(-13)	26.7	.575(-13)	21.8	.280(-12)	12.8	.395(-10)	1.0

$\pi\hbar(v+1/2)$; (3) finally the continuous rotational and vibrational numbers are made discrete by rounding them to the nearest integer.¹³

3. Tables of Results

Fixed temperature rate coefficients calculated using the above described method are given in all tables separated per process and per pair of initial vibrational numbers. In all the tables the calculated values are presented in the format $a(x)$ followed by the percentual error. The format adopted corresponds to the notation $a \cdot 10^x \text{ cm}^3 \text{ molecule}^{-1} \text{ s}^{-1}$.

Calculated rate coefficients are reported in the following order:

- (i) $\text{H}_2 + \text{H}_2$ nonreactive values (Tables 1– 15);
- (ii) $\text{H}_2 + \text{H}_2$ reactive values (Tables 16– 30); and
- (iii) $\text{H}_2 + \text{H}_2$ dissociative values (Tables 31–33).

The value of nonreactive rate coefficients has to be taken with some caution. As is well known, elastic ($v_{1-2}=v'_{1-2}$ and $v_{3-4}=v'_{3-4}$) rates are by definition unconverged. Inelastic quantities are less accurate than reactive ones because of their slower convergence with b and of the poorer performance of the adopted discretization method.

TABLE 2. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂=7)+H₃-H₄(v₃₋₄) rate coefficients at T=1000 K (H₂+H₂ nonreactive values)

v'	v ₃₋₄ =5		v ₃₋₄ =7		v ₃₋₄ =9		v ₃₋₄ =11		v ₃₋₄ =13	
0	.295(-11)	3.1	.588(-11)	2.9	.769(-11)	2.6	.720(-11)	2.8	.716(-11)	2.7
1	.324(-11)	3.0	.667(-11)	2.7	.710(-11)	2.7	.735(-11)	2.8	.678(-11)	2.8
2	.418(-11)	2.6	.763(-11)	2.6	.791(-11)	2.6	.813(-11)	2.7	.762(-11)	2.6
3	.762(-11)	1.9	.932(-11)	2.3	.892(-11)	2.4	.101(-10)	2.4	.975(-11)	2.3
4	.382(-10)	0.9	.103(-10)	2.2	.951(-11)	2.3	.117(-10)	2.2	.120(-10)	2.1
5	.106(-08)	0.1	.147(-10)	1.8	.114(-10)	2.1	.142(-10)	2.0	.148(-10)	1.9
6	.377(-10)	0.9	.150(-09)	0.6	.410(-10)	1.1	.475(-10)	1.1	.258(-10)	1.4
7	.106(-08)	0.1	.182(-08)	0.1	.945(-09)	0.2	.907(-09)	0.2	.179(-08)	0.1
8	.426(-10)	0.8	.150(-09)	0.6	.144(-09)	0.6	.332(-10)	1.3	.249(-10)	1.4
9	.612(-11)	2.2	.128(-10)	2.0	.921(-09)	0.2	.138(-10)	2.0	.574(-11)	3.0
10	.210(-11)	3.7	.586(-11)	2.9	.447(-10)	1.1	.640(-10)	0.9	.811(-11)	2.5
11	.125(-11)	4.8	.306(-11)	4.0	.560(-11)	3.1	.782(-09)	0.2	.233(-10)	1.5
12	.547(-12)	7.3	.146(-11)	5.9	.216(-11)	4.9	.105(-09)	0.7	.816(-10)	0.8
13	.190(-12)	12.3	.525(-12)	9.8	.774(-12)	8.2	.936(-11)	2.5	.147(-08)	0.2
14	.403(-13)	26.7	.120(-12)	20.4	.146(-12)	18.9	.869(-12)	8.1	.468(-10)	1.1

TABLE 3. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂=9)+H₃-H₄(v₃₋₄) rate coefficients at T=1000 K (H₂+H₂ nonreactive values)

v'	v ₃₋₄ =5		v ₃₋₄ =7		v ₃₋₄ =9		v ₃₋₄ =11		v ₃₋₄ =13	
0	.606(-11)	2.1	.769(-11)	2.6	.759(-11)	2.6	.763(-11)	3.2	.649(-11)	3.4
1	.623(-11)	2.1	.710(-11)	2.7	.717(-11)	2.6	.754(-11)	3.2	.635(-11)	3.5
2	.689(-11)	2.0	.791(-11)	2.6	.889(-11)	2.4	.837(-11)	3.0	.772(-11)	3.1
3	.845(-11)	1.8	.892(-11)	2.4	.106(-10)	2.2	.991(-11)	2.8	.968(-11)	2.8
4	.362(-10)	0.9	.951(-11)	2.3	.133(-10)	1.9	.118(-10)	2.5	.119(-10)	2.5
5	.101(-08)	0.1	.114(-10)	2.1	.171(-10)	1.7	.143(-10)	2.3	.148(-10)	2.3
6	.497(-10)	0.7	.410(-10)	1.1	.192(-10)	1.6	.163(-10)	2.2	.181(-10)	2.1
7	.884(-11)	1.8	.945(-09)	0.2	.249(-10)	1.4	.189(-10)	2.0	.230(-10)	1.8
8	.744(-10)	0.6	.144(-09)	0.6	.189(-09)	0.5	.507(-10)	1.2	.350(-10)	1.5
9	.959(-09)	0.1	.921(-09)	0.2	.149(-08)	0.1	.821(-09)	0.2	.161(-08)	0.2
10	.569(-10)	0.7	.447(-10)	1.1	.194(-09)	0.5	.595(-10)	1.1	.196(-10)	2.0
11	.552(-11)	2.2	.560(-11)	3.1	.129(-10)	2.0	.763(-09)	0.3	.136(-10)	2.4
12	.156(-11)	4.2	.216(-11)	4.9	.467(-11)	3.3	.586(-10)	1.1	.574(-10)	1.1
13	.553(-12)	7.0	.774(-12)	8.2	.180(-11)	5.3	.942(-11)	2.8	.136(-08)	0.2
14	.575(-13)	21.8	.146(-12)	18.9	.300(-12)	12.9	.106(-11)	8.5	.464(-10)	1.3

TABLE 4. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂=11)+H₃-H₄(v₃₋₄) rate coefficients at T=1000 K (H₂+H₂ nonreactive values)

v'	v ₃₋₄ =5		v ₃₋₄ =7		v ₃₋₄ =9		v ₃₋₄ =11		v ₃₋₄ =13	
0	.661(-11)	2.6	.720(-11)	2.8	.763(-11)	3.2	.780(-11)	3.2	.609(-11)	4.3
1	.664(-11)	2.6	.735(-11)	2.8	.754(-11)	3.2	.783(-11)	3.2	.677(-11)	4.1
2	.729(-11)	2.5	.813(-11)	2.7	.837(-11)	3.0	.924(-11)	3.0	.846(-11)	3.7
3	.907(-11)	2.2	.101(-10)	2.4	.991(-11)	2.8	.115(-10)	2.7	.102(-10)	3.3
4	.208(-10)	1.5	.117(-10)	2.2	.118(-10)	2.5	.130(-10)	2.5	.132(-10)	2.9
5	.102(-08)	0.2	.142(-10)	2.0	.143(-10)	2.3	.159(-10)	2.3	.168(-10)	2.6
6	.162(-10)	1.7	.475(-10)	1.1	.163(-10)	2.2	.188(-10)	2.1	.201(-10)	2.4
7	.527(-11)	3.0	.907(-09)	0.2	.189(-10)	2.0	.213(-10)	2.0	.250(-10)	2.1
8	.554(-11)	2.9	.332(-10)	1.3	.507(-10)	1.2	.237(-10)	1.9	.302(-10)	1.9
9	.101(-10)	2.1	.138(-10)	2.0	.821(-09)	0.2	.247(-10)	1.8	.352(-10)	1.8
10	.554(-10)	0.9	.640(-10)	0.9	.595(-10)	1.1	.750(-10)	1.0	.463(-10)	1.6
11	.927(-09)	0.2	.782(-09)	0.2	.763(-09)	0.3	.171(-08)	0.1	.126(-08)	0.3
12	.519(-10)	0.9	.105(-09)	0.7	.586(-10)	1.1	.744(-10)	1.0	.569(-10)	1.4
13	.433(-11)	3.3	.936(-11)	2.5	.942(-11)	2.8	.737(-11)	3.3	.115(-08)	0.3
14	.280(-12)	12.8	.869(-12)	8.1	.106(-11)	8.5	.108(-11)	8.7	.185(-10)	2.5

TABLE 5. Vibrational state-to-state nonreactive $H_1-H_2(v_{1-2}=13)+H_3-H_4(v_{3-4})$ rate coefficients at $T=1000$ K (H_2+H_2 nonreactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.711(-11)	2.4	.716(-11)	2.7	.649(-11)	3.4	.609(-11)	4.3	.548(-11)	4.6
1	.741(-11)	2.4	.678(-11)	2.8	.635(-11)	3.5	.677(-11)	4.1	.566(-11)	4.5
2	.822(-11)	2.2	.762(-11)	2.6	.772(-11)	3.1	.846(-11)	3.7	.746(-11)	3.9
3	.103(-10)	2.0	.975(-11)	2.3	.968(-11)	2.8	.102(-10)	3.3	.985(-11)	3.4
4	.154(-10)	1.6	.120(-10)	2.1	.119(-10)	2.5	.132(-10)	2.9	.125(-10)	3.0
5	.192(-08)	0.1	.148(-10)	1.9	.148(-10)	2.3	.168(-10)	2.6	.164(-10)	2.6
6	.645(-11)	2.5	.258(-10)	1.4	.181(-10)	2.1	.201(-10)	2.4	.211(-10)	2.3
7	.236(-11)	4.2	.179(-08)	0.1	.230(-10)	1.8	.250(-10)	2.1	.282(-10)	2.0
8	.250(-11)	4.1	.249(-10)	1.4	.350(-10)	1.5	.302(-10)	1.9	.350(-10)	1.8
9	.306(-11)	3.7	.574(-11)	3.0	.161(-08)	0.2	.352(-10)	1.8	.424(-10)	1.6
10	.559(-11)	2.7	.811(-11)	2.5	.196(-10)	2.0	.463(-10)	1.6	.503(-10)	1.5
11	.160(-10)	1.6	.233(-10)	1.5	.136(-10)	2.4	.126(-08)	0.3	.554(-10)	1.4
12	.741(-10)	0.7	.816(-10)	0.8	.574(-10)	1.1	.569(-10)	1.4	.825(-10)	1.2
13	.161(-08)	0.1	.147(-08)	0.2	.136(-08)	0.2	.115(-08)	0.3	.213(-08)	0.2
14	.395(-10)	1.0	.468(-10)	1.1	.464(-10)	1.3	.185(-10)	2.5	.386(-10)	1.7

TABLE 6. Vibrational state-to-state nonreactive $H_1-H_2(v_{1-2}=5)+H_3-H_4(v_{3-4})$ rate coefficients at $T=2000$ K (H_2+H_2 nonreactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.310(-11)	3.4	.756(-11)	2.8	.118(-10)	2.0	.127(-10)	2.2	.115(-10)	2.9
1	.513(-11)	2.7	.808(-11)	2.7	.123(-10)	2.0	.118(-10)	2.3	.117(-10)	2.9
2	.735(-11)	2.2	.995(-11)	2.4	.136(-10)	1.9	.139(-10)	2.1	.139(-10)	2.6
3	.189(-10)	1.4	.168(-10)	1.9	.179(-10)	1.6	.184(-10)	1.8	.171(-10)	2.4
4	.278(-09)	0.3	.748(-10)	0.9	.623(-10)	0.9	.423(-10)	1.2	.325(-10)	1.7
5	.261(-08)	0.1	.143(-08)	0.2	.136(-08)	0.1	.134(-08)	0.2	.262(-08)	0.1
6	.284(-09)	0.3	.977(-10)	0.8	.655(-10)	0.8	.321(-10)	1.4	.156(-10)	2.5
7	.175(-10)	1.4	.140(-08)	0.2	.228(-10)	1.4	.101(-10)	2.5	.456(-11)	4.6
8	.530(-11)	2.6	.864(-10)	0.8	.107(-09)	0.7	.128(-10)	2.2	.448(-11)	4.6
9	.258(-11)	3.7	.133(-10)	2.1	.127(-08)	0.2	.239(-10)	1.6	.606(-11)	4.0
10	.124(-11)	5.4	.450(-11)	3.6	.906(-10)	0.7	.104(-09)	0.8	.110(-10)	2.9
11	.698(-12)	7.2	.241(-11)	4.9	.122(-10)	2.0	.114(-08)	0.2	.289(-10)	1.8
12	.285(-12)	11.3	.111(-11)	7.2	.353(-11)	3.7	.887(-10)	0.8	.105(-09)	0.9
13	.651(-13)	23.6	.383(-12)	12.3	.108(-11)	6.7	.909(-11)	2.6	.213(-08)	0.2
14			.581(-13)	31.6	.129(-12)	19.2	.927(-12)	8.2	.520(-10)	1.4

TABLE 7. Vibrational state-to-state nonreactive $H_1-H_2(v_{1-2}=7)+H_3-H_4(v_{3-4})$ rate coefficients at $T=2000$ K (H_2+H_2 nonreactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.756(-11)	2.8	.133(-10)	2.3	.148(-10)	2.2	.141(-10)	2.4	.116(-10)	3.1
1	.808(-11)	2.7	.125(-10)	2.3	.136(-10)	2.3	.130(-10)	2.5	.117(-10)	3.0
2	.995(-11)	2.4	.134(-10)	2.2	.146(-10)	2.2	.141(-10)	2.4	.132(-10)	2.9
3	.168(-10)	1.9	.162(-10)	2.0	.160(-10)	2.1	.159(-10)	2.3	.160(-10)	2.6
4	.748(-10)	0.9	.190(-10)	1.9	.177(-10)	2.0	.195(-10)	2.0	.188(-10)	2.4
5	.143(-08)	0.2	.348(-10)	1.4	.235(-10)	1.8	.247(-10)	1.8	.251(-10)	2.1
6	.977(-10)	0.8	.281(-09)	0.5	.820(-10)	0.9	.793(-10)	1.0	.507(-10)	1.5
7	.140(-08)	0.2	.232(-08)	0.1	.119(-08)	0.2	.131(-08)	0.2	.240(-08)	0.2
8	.864(-10)	0.8	.264(-09)	0.5	.271(-09)	0.5	.592(-10)	1.2	.406(-10)	1.6
9	.133(-10)	2.1	.255(-10)	1.6	.114(-08)	0.2	.307(-10)	1.6	.101(-10)	3.3
10	.450(-11)	3.6	.855(-11)	2.8	.826(-10)	0.9	.116(-09)	0.8	.127(-10)	2.9
11	.241(-11)	4.9	.441(-11)	3.9	.120(-10)	2.5	.110(-08)	0.2	.349(-10)	1.8
12	.111(-11)	7.2	.198(-11)	5.8	.456(-11)	4.0	.134(-09)	0.8	.119(-09)	0.9
13	.383(-12)	12.3	.895(-12)	8.7	.134(-11)	7.4	.144(-10)	2.4	.191(-08)	0.2
14	.581(-13)	31.6	.108(-12)	25.0	.192(-12)	19.6	.141(-11)	7.6	.611(-10)	1.3

TABLE 8. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂= 9)+H₃-H₄(v₃₋₄) rate coefficients at T=2000 K (H₂+H₂ nonreactive values)

v'	v ₃₋₄ = 5		v ₃₋₄ = 7		v ₃₋₄ = 9		v ₃₋₄ =11		v ₃₋₄ =13	
0	.118(-10)	2.0	.148(-10)	2.2	.134(-10)	2.8	.138(-10)	3.4	.103(-10)	4.0
1	.123(-10)	2.0	.136(-10)	2.3	.130(-10)	2.9	.127(-10)	3.6	.102(-10)	4.0
2	.136(-10)	1.9	.146(-10)	2.2	.147(-10)	2.7	.140(-10)	3.4	.120(-10)	3.7
3	.179(-10)	1.6	.160(-10)	2.1	.176(-10)	2.5	.158(-10)	3.2	.144(-10)	3.3
4	.623(-10)	0.9	.177(-10)	2.0	.216(-10)	2.2	.181(-10)	3.0	.166(-10)	3.1
5	.136(-08)	0.1	.235(-10)	1.8	.257(-10)	2.0	.223(-10)	2.7	.223(-10)	2.7
6	.655(-10)	0.8	.820(-10)	0.9	.303(-10)	1.9	.265(-10)	2.5	.268(-10)	2.4
7	.228(-10)	1.4	.119(-08)	0.2	.456(-10)	1.5	.339(-10)	2.2	.337(-10)	2.2
8	.107(-09)	0.7	.271(-09)	0.5	.269(-09)	0.6	.808(-10)	1.4	.588(-10)	1.6
9	.127(-08)	0.2	.114(-08)	0.2	.188(-08)	0.2	.114(-08)	0.3	.211(-08)	0.2
10	.906(-10)	0.7	.826(-10)	0.9	.248(-09)	0.6	.114(-09)	1.2	.366(-10)	2.1
11	.122(-10)	2.0	.120(-10)	2.5	.211(-10)	2.3	.103(-08)	0.3	.224(-10)	2.7
12	.353(-11)	3.7	.456(-11)	4.0	.704(-11)	3.9	.853(-10)	1.4	.786(-10)	1.4
13	.108(-11)	6.7	.134(-11)	7.4	.245(-11)	6.6	.120(-10)	3.7	.178(-08)	0.3
14	.129(-12)	19.2	.192(-12)	19.6	.488(-12)	14.9	.148(-11)	10.5	.477(-10)	1.8

TABLE 9. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂=11)+H₃-H₄(v₃₋₄) rate coefficients at T=2000 K (H₂+H₂ nonreactive values)

v'	v ₃₋₄ = 5		v ₃₋₄ = 7		v ₃₋₄ = 9		v ₃₋₄ =11		v ₃₋₄ =13	
0	.127(-10)	2.2	.141(-10)	2.4	.138(-10)	3.4	.124(-10)	3.6	.929(-11)	4.2
1	.118(-10)	2.3	.130(-10)	2.5	.127(-10)	3.6	.124(-10)	3.6	.926(-11)	4.2
2	.139(-10)	2.1	.141(-10)	2.4	.140(-10)	3.4	.146(-10)	3.3	.116(-10)	3.7
3	.184(-10)	1.8	.159(-10)	2.3	.158(-10)	3.2	.172(-10)	3.1	.135(-10)	3.5
4	.423(-10)	1.2	.195(-10)	2.0	.181(-10)	3.0	.191(-10)	2.9	.169(-10)	3.1
5	.134(-08)	0.2	.247(-10)	1.8	.223(-10)	2.7	.222(-10)	2.7	.226(-10)	2.7
6	.321(-10)	1.4	.793(-10)	1.0	.265(-10)	2.5	.277(-10)	2.4	.272(-10)	2.4
7	.101(-10)	2.5	.131(-08)	0.2	.339(-10)	2.2	.319(-10)	2.2	.341(-10)	2.2
8	.128(-10)	2.2	.592(-10)	1.2	.808(-10)	1.4	.364(-10)	2.1	.398(-10)	2.0
9	.239(-10)	1.6	.307(-10)	1.6	.114(-08)	0.3	.460(-10)	1.9	.491(-10)	1.8
10	.104(-09)	0.8	.116(-09)	0.8	.114(-09)	1.2	.134(-09)	1.1	.753(-10)	1.5
11	.114(-08)	0.2	.110(-08)	0.2	.103(-08)	0.3	.233(-08)	0.2	.168(-08)	0.3
12	.887(-10)	0.8	.134(-09)	0.8	.853(-10)	1.4	.119(-09)	1.2	.101(-09)	1.3
13	.909(-11)	2.6	.144(-10)	2.4	.120(-10)	3.7	.134(-10)	3.5	.153(-08)	0.3
14	.927(-12)	8.2	.141(-11)	7.6	.148(-11)	10.5	.179(-11)	9.5	.271(-10)	2.4

TABLE 10. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂=13)+H₃-H₄(v₃₋₄) rate coefficients at T=2000 K (H₂+H₂ nonreactive values)

v'	v ₃₋₄ = 5		v ₃₋₄ = 7		v ₃₋₄ = 9		v ₃₋₄ =11		v ₃₋₄ =13	
0	.115(-10)	2.9	.116(-10)	3.1	.103(-10)	4.0	.929(-11)	4.2	.785(-11)	4.4
1	.117(-10)	2.9	.117(-10)	3.0	.102(-10)	4.0	.926(-11)	4.2	.799(-11)	4.4
2	.139(-10)	2.6	.132(-10)	2.9	.120(-10)	3.7	.116(-10)	3.7	.975(-11)	3.9
3	.171(-10)	2.4	.160(-10)	2.6	.144(-10)	3.3	.135(-10)	3.5	.116(-10)	3.6
4	.325(-10)	1.7	.188(-10)	2.4	.166(-10)	3.1	.169(-10)	3.1	.160(-10)	3.1
5	.262(-08)	0.1	.251(-10)	2.1	.223(-10)	2.7	.226(-10)	2.7	.204(-10)	2.7
6	.156(-10)	2.5	.507(-10)	1.5	.268(-10)	2.4	.272(-10)	2.4	.262(-10)	2.4
7	.456(-11)	4.6	.240(-08)	0.2	.337(-10)	2.2	.341(-10)	2.2	.335(-10)	2.1
8	.448(-11)	4.6	.406(-10)	1.6	.588(-10)	1.6	.398(-10)	2.0	.415(-10)	1.9
9	.606(-11)	4.0	.101(-10)	3.3	.211(-08)	0.2	.491(-10)	1.8	.509(-10)	1.7
10	.110(-10)	2.9	.127(-10)	2.9	.366(-10)	2.1	.753(-10)	1.5	.582(-10)	1.6
11	.289(-10)	1.8	.349(-10)	1.8	.224(-10)	2.7	.168(-08)	0.3	.713(-10)	1.5
12	.105(-09)	0.9	.119(-09)	0.9	.786(-10)	1.4	.101(-09)	1.3	.128(-09)	1.1
13	.213(-08)	0.2	.191(-08)	0.2	.178(-08)	0.3	.153(-08)	0.3	.312(-08)	0.2
14	.520(-10)	1.4	.611(-10)	1.3	.477(-10)	1.8	.271(-10)	2.4	.585(-10)	1.6

TABLE 11. Vibrational state-to-state nonreactive $H_1-H_2(v_{1-2}=5)+H_3-H_4(v_{3-4})$ rate coefficients at $T=4000$ K (H_2+H_2 nonreactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.993(-11)	2.8	.176(-10)	2.7	.191(-10)	2.6	.199(-10)	2.5	.177(-10)	2.9
1	.132(-10)	2.4	.169(-10)	2.7	.199(-10)	2.5	.203(-10)	2.4	.185(-10)	2.9
2	.182(-10)	2.1	.202(-10)	2.5	.228(-10)	2.4	.221(-10)	2.3	.217(-10)	2.7
3	.416(-10)	1.4	.324(-10)	2.0	.328(-10)	2.0	.320(-10)	1.9	.284(-10)	2.3
4	.324(-09)	0.5	.120(-09)	1.0	.977(-10)	1.1	.809(-10)	1.2	.660(-10)	1.5
5	.370(-08)	0.1	.190(-08)	0.2	.181(-08)	0.2	.174(-08)	0.2	.353(-08)	0.2
6	.327(-09)	0.5	.207(-09)	0.8	.101(-09)	1.1	.614(-10)	1.4	.413(-10)	1.9
7	.349(-10)	1.5	.183(-08)	0.2	.472(-10)	1.6	.193(-10)	2.5	.110(-10)	3.7
8	.116(-10)	2.6	.133(-09)	1.0	.157(-09)	0.9	.209(-10)	2.4	.690(-11)	4.7
9	.549(-11)	3.8	.237(-10)	2.3	.165(-08)	0.2	.417(-10)	1.7	.912(-11)	4.1
10	.309(-11)	5.1	.894(-11)	3.8	.128(-09)	1.0	.152(-09)	0.9	.155(-10)	3.1
11	.157(-11)	7.1	.426(-11)	5.5	.210(-10)	2.5	.145(-08)	0.2	.375(-10)	2.0
12	.635(-12)	11.2	.184(-11)	8.3	.588(-11)	4.7	.124(-09)	1.0	.131(-09)	1.1
13	.262(-12)	17.4	.614(-12)	14.4	.112(-11)	10.7	.141(-10)	2.9	.292(-08)	0.2
14			.115(-12)	33.3	.230(-12)	23.6	.134(-11)	9.5	.645(-10)	1.5

TABLE 12. Vibrational state-to-state nonreactive $H_1-H_2(v_{1-2}=7)+H_3-H_4(v_{3-4})$ rate coefficients at $T=4000$ K (H_2+H_2 nonreactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.176(-10)	2.7	.215(-10)	2.8	.227(-10)	2.4	.210(-10)	2.9	.159(-10)	3.8
1	.169(-10)	2.7	.211(-10)	2.8	.209(-10)	2.5	.204(-10)	2.9	.155(-10)	3.8
2	.202(-10)	2.5	.225(-10)	2.7	.217(-10)	2.5	.215(-10)	2.9	.184(-10)	3.5
3	.324(-10)	2.0	.245(-10)	2.6	.251(-10)	2.3	.234(-10)	2.7	.221(-10)	3.2
4	.120(-09)	1.0	.316(-10)	2.3	.285(-10)	2.2	.297(-10)	2.4	.267(-10)	2.9
5	.190(-08)	0.2	.661(-10)	1.6	.400(-10)	1.8	.388(-10)	2.1	.378(-10)	2.5
6	.207(-09)	0.8	.398(-09)	0.6	.144(-09)	1.0	.117(-09)	1.2	.873(-10)	1.6
7	.183(-08)	0.2	.303(-08)	0.1	.152(-08)	0.2	.168(-08)	0.3	.319(-08)	0.2
8	.133(-09)	1.0	.363(-09)	0.6	.370(-09)	0.6	.953(-10)	1.4	.658(-10)	1.9
9	.237(-10)	2.3	.456(-10)	1.9	.142(-08)	0.3	.482(-10)	1.9	.193(-10)	3.4
10	.894(-11)	3.8	.128(-10)	3.6	.137(-09)	1.0	.168(-09)	1.0	.196(-10)	3.4
11	.426(-11)	5.5	.598(-11)	5.2	.216(-10)	2.5	.141(-08)	0.3	.401(-10)	2.4
12	.184(-11)	8.3	.297(-11)	7.4	.677(-11)	4.5	.155(-09)	1.1	.143(-09)	1.3
13	.614(-12)	14.4	.103(-11)	12.6	.188(-11)	8.5	.186(-10)	3.1	.263(-08)	0.2
14	.115(-12)	33.3	.131(-12)	35.4	.284(-12)	21.8	.163(-11)	10.4	.719(-10)	1.8

TABLE 13. Vibrational state-to-state nonreactive $H_1-H_2(v_{1-2}=9)+H_3-H_4(v_{3-4})$ rate coefficients at $T=4000$ K (H_2+H_2 nonreactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.191(-10)	2.6	.227(-10)	2.4	.205(-10)	3.3	.194(-10)	3.4	.127(-10)	4.2
1	.199(-10)	2.5	.209(-10)	2.5	.193(-10)	3.4	.180(-10)	3.6	.132(-10)	4.2
2	.228(-10)	2.4	.217(-10)	2.5	.207(-10)	3.3	.190(-10)	3.5	.147(-10)	3.9
3	.328(-10)	2.0	.251(-10)	2.3	.242(-10)	3.1	.220(-10)	3.2	.192(-10)	3.5
4	.977(-10)	1.1	.285(-10)	2.2	.269(-10)	2.9	.243(-10)	3.1	.239(-10)	3.1
5	.181(-08)	0.2	.400(-10)	1.8	.316(-10)	2.7	.295(-10)	2.8	.284(-10)	2.8
6	.101(-09)	1.1	.144(-09)	1.0	.411(-10)	2.4	.361(-10)	2.5	.353(-10)	2.5
7	.472(-10)	1.6	.152(-08)	0.2	.651(-10)	1.9	.480(-10)	2.2	.489(-10)	2.2
8	.157(-09)	0.9	.370(-09)	0.6	.311(-09)	0.8	.114(-09)	1.4	.915(-10)	1.6
9	.165(-08)	0.2	.142(-08)	0.3	.295(-08)	0.2	.168(-08)	0.3	.282(-08)	0.2
10	.128(-09)	1.0	.137(-09)	1.0	.273(-09)	0.9	.177(-09)	1.1	.675(-10)	1.8
11	.210(-10)	2.5	.216(-10)	2.5	.322(-10)	2.7	.154(-08)	0.3	.388(-10)	2.4
12	.588(-11)	4.7	.677(-11)	4.5	.898(-11)	5.1	.106(-09)	1.5	.987(-10)	1.5
13	.112(-11)	10.7	.188(-11)	8.5	.292(-11)	8.9	.144(-10)	4.0	.247(-08)	0.3
14	.230(-12)	23.6	.284(-12)	21.8	.575(-12)	20.0	.207(-11)	10.5	.522(-10)	2.1

TABLE 14. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂=11)+H₃-H₄(v₃₋₄) rate coefficients at T=4000 K (H₂+H₂ nonreactive values)

<i>v</i> '	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.199(-10)	2.5	.210(-10)	2.9	.194(-10)	3.4	.174(-10)	3.6	.137(-10)	4.1
1	.203(-10)	2.4	.204(-10)	2.9	.180(-10)	3.6	.166(-10)	3.7	.121(-10)	4.3
2	.221(-10)	2.3	.215(-10)	2.9	.190(-10)	3.5	.197(-10)	3.4	.157(-10)	3.8
3	.320(-10)	1.9	.234(-10)	2.7	.220(-10)	3.2	.218(-10)	3.2	.181(-10)	3.6
4	.809(-10)	1.2	.297(-10)	2.4	.243(-10)	3.1	.258(-10)	3.0	.225(-10)	3.2
5	.174(-08)	0.2	.388(-10)	2.1	.295(-10)	2.8	.300(-10)	2.8	.277(-10)	2.9
6	.614(-10)	1.4	.117(-09)	1.2	.361(-10)	2.5	.368(-10)	2.5	.345(-10)	2.6
7	.193(-10)	2.5	.168(-08)	0.3	.480(-10)	2.2	.414(-10)	2.4	.424(-10)	2.3
8	.209(-10)	2.4	.953(-10)	1.4	.114(-09)	1.4	.485(-10)	2.2	.517(-10)	2.1
9	.417(-10)	1.7	.482(-10)	1.9	.168(-08)	0.3	.698(-10)	1.8	.635(-10)	1.9
10	.152(-09)	0.9	.168(-09)	1.0	.177(-09)	1.1	.210(-09)	1.0	.116(-09)	1.4
11	.145(-08)	0.2	.141(-08)	0.3	.154(-08)	0.3	.303(-08)	0.2	.234(-08)	0.3
12	.124(-09)	1.0	.155(-09)	1.1	.106(-09)	1.5	.171(-09)	1.1	.160(-09)	1.2
13	.141(-10)	2.9	.186(-10)	3.1	.144(-10)	4.0	.201(-10)	3.4	.216(-08)	0.3
14	.134(-11)	9.5	.163(-11)	10.4	.207(-11)	10.5	.285(-11)	9.0	.424(-10)	2.3

TABLE 15. Vibrational state-to-state nonreactive H₁-H₂(v₁₋₂=13)+H₃-H₄(v₃₋₄) rate coefficients at T=4000 K (H₂+H₂ nonreactive values)

<i>v</i> '	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.177(-10)	2.9	.159(-10)	3.8	.127(-10)	4.2	.137(-10)	4.1	.991(-11)	4.0
1	.185(-10)	2.9	.155(-10)	3.8	.132(-10)	4.2	.121(-10)	4.3	.995(-11)	4.0
2	.217(-10)	2.7	.184(-10)	3.5	.147(-10)	3.9	.157(-10)	3.8	.120(-10)	3.6
3	.284(-10)	2.3	.221(-10)	3.2	.192(-10)	3.5	.181(-10)	3.6	.149(-10)	3.2
4	.660(-10)	1.5	.267(-10)	2.9	.239(-10)	3.1	.225(-10)	3.2	.195(-10)	2.8
5	.353(-08)	0.2	.378(-10)	2.5	.284(-10)	2.8	.277(-10)	2.9	.249(-10)	2.5
6	.413(-10)	1.9	.873(-10)	1.6	.353(-10)	2.5	.345(-10)	2.6	.336(-10)	2.2
7	.110(-10)	3.7	.319(-08)	0.2	.489(-10)	2.2	.424(-10)	2.3	.407(-10)	2.0
8	.690(-11)	4.7	.658(-10)	1.9	.915(-10)	1.6	.517(-10)	2.1	.480(-10)	1.8
9	.912(-11)	4.1	.193(-10)	3.4	.282(-08)	0.2	.635(-10)	1.9	.581(-10)	1.6
10	.155(-10)	3.1	.196(-10)	3.4	.675(-10)	1.8	.116(-09)	1.4	.725(-10)	1.5
11	.375(-10)	2.0	.401(-10)	2.4	.388(-10)	2.4	.234(-08)	0.3	.939(-10)	1.3
12	.131(-09)	1.1	.143(-09)	1.3	.987(-10)	1.5	.160(-09)	1.2	.196(-09)	0.9
13	.292(-08)	0.2	.263(-08)	0.2	.247(-08)	0.3	.216(-08)	0.3	.462(-08)	0.1
14	.645(-10)	1.5	.719(-10)	1.8	.522(-10)	2.1	.424(-10)	2.3	.932(-10)	1.3

TABLE 16. Vibrational state-to-state reactive H₁-H₂(v₁₋₂=5)+H₃-H₄(v₃₋₄) rate coefficients at T=1000 K (H₂+H₂ reactive values)

<i>v</i> '	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.523(-12)	6.1	.251(-11)	3.4	.356(-11)	2.8	.560(-11)	2.9	.832(-11)	2.2
1	.124(-12)	12.4	.615(-11)	2.2	.711(-11)	2.0	.828(-11)	2.4	.112(-10)	1.9
2			.310(-11)	3.0	.103(-10)	1.6	.131(-10)	1.9	.163(-10)	1.6
3			.192(-12)	12.2	.823(-11)	1.8	.180(-10)	1.6	.250(-10)	1.3
4			.138(-12)	14.4	.699(-12)	6.3	.152(-10)	1.7	.399(-10)	1.0
5			.126(-12)	15.1	.260(-12)	10.3	.173(-11)	5.2	.206(-10)	1.4
6			.118(-12)	15.6	.287(-12)	9.8	.492(-12)	9.7	.159(-11)	5.1
7			.633(-13)	21.3	.230(-12)	10.9	.433(-12)	10.3	.101(-11)	6.4
8			.662(-13)	20.9	.183(-12)	12.2	.313(-12)	12.1	.937(-12)	6.6
9			.431(-13)	25.8	.128(-12)	14.6	.317(-12)	12.0	.925(-12)	6.7
10					.767(-13)	18.9	.340(-12)	11.6	.954(-12)	6.6
11					.850(-13)	18.0	.382(-12)	11.0	.921(-12)	6.7
12					.658(-13)	20.4	.290(-12)	12.6	.104(-11)	6.3
13					.658(-13)	20.4	.244(-12)	13.7	.945(-12)	6.6
14					.466(-13)	24.3	.133(-12)	18.6	.390(-12)	10.3

TABLE 17. Vibrational state-to-state reactive $\text{H}_1\text{-H}_2(v_{1-2}=7)+\text{H}_3\text{-H}_4(v_{3-4})$ rate coefficients at $T=1000\text{ K}$ (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.251(-11)	3.4	.413(-11)	3.5	.608(-11)	2.9	.724(-11)	2.8	.940(-11)	2.4
1	.615(-11)	2.2	.861(-11)	2.4	.782(-11)	2.6	.921(-11)	2.5	.104(-10)	2.2
2	.310(-11)	3.0	.139(-10)	1.9	.112(-10)	2.2	.129(-10)	2.1	.139(-10)	1.9
3	.192(-12)	12.2	.142(-10)	1.9	.139(-10)	1.9	.167(-10)	1.8	.198(-10)	1.6
4	.138(-12)	14.4	.210(-11)	4.9	.145(-10)	1.9	.220(-10)	1.6	.280(-10)	1.4
5	.126(-12)	15.1	.550(-12)	9.5	.570(-11)	3.0	.275(-10)	1.4	.383(-10)	1.2
6	.118(-12)	15.6	.345(-12)	12.0	.106(-11)	7.0	.180(-10)	1.8	.507(-10)	1.0
7	.633(-13)	21.3	.375(-12)	11.5	.659(-12)	8.9	.252(-11)	4.8	.242(-10)	1.5
8	.662(-13)	20.9	.365(-12)	11.7	.570(-12)	9.6	.143(-11)	6.3	.371(-11)	3.8
9	.431(-13)	25.8	.235(-12)	14.6	.492(-12)	10.3	.122(-11)	6.9	.234(-11)	4.7
10			.190(-12)	16.2	.350(-12)	12.2	.863(-12)	8.2	.201(-11)	5.1
11			.190(-12)	16.2	.408(-12)	11.3	.944(-12)	7.8	.196(-11)	5.2
12			.175(-12)	16.9	.350(-12)	12.2	.915(-12)	7.9	.186(-11)	5.3
13			.105(-12)	21.8	.235(-12)	14.9	.673(-12)	9.2	.156(-11)	5.8
14			.700(-13)	26.7	.141(-12)	19.2	.247(-12)	15.2	.848(-12)	7.9

TABLE 18. Vibrational state-to-state reactive $\text{H}_1\text{-H}_2(v_{1-2}=9)+\text{H}_3\text{-H}_4(v_{3-4})$ rate coefficients at $T=1000\text{ K}$ (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.356(-11)	2.8	.608(-11)	2.9	.708(-11)	2.7	.860(-11)	3.0	.100(-10)	2.8
1	.711(-11)	2.0	.782(-11)	2.6	.917(-11)	2.3	.104(-10)	2.7	.108(-10)	2.7
2	.103(-10)	1.6	.112(-10)	2.2	.127(-10)	2.0	.131(-10)	2.4	.142(-10)	2.3
3	.823(-11)	1.8	.139(-10)	1.9	.172(-10)	1.7	.171(-10)	2.1	.186(-10)	2.0
4	.699(-12)	6.3	.145(-10)	1.9	.219(-10)	1.5	.200(-10)	1.9	.258(-10)	1.7
5	.260(-12)	10.3	.570(-11)	3.0	.272(-10)	1.3	.254(-10)	1.7	.337(-10)	1.5
6	.287(-12)	9.8	.106(-11)	7.0	.240(-10)	1.4	.311(-10)	1.6	.475(-10)	1.3
7	.230(-12)	10.9	.659(-12)	8.9	.525(-11)	3.1	.362(-10)	1.4	.638(-10)	1.1
8	.183(-12)	12.2	.570(-12)	9.6	.213(-11)	4.8	.189(-10)	2.0	.761(-10)	1.0
9	.128(-12)	14.6	.492(-12)	10.3	.169(-11)	5.4	.485(-11)	4.0	.370(-10)	1.4
10	.767(-13)	18.9	.350(-12)	12.2	.140(-11)	6.0	.283(-11)	5.2	.872(-11)	3.0
11	.850(-13)	18.0	.408(-12)	11.3	.124(-11)	6.3	.230(-11)	5.8	.543(-11)	3.8
12	.658(-13)	20.4	.350(-12)	12.2	.113(-11)	6.6	.214(-11)	6.0	.434(-11)	4.2
13	.658(-13)	20.4	.235(-12)	14.9	.951(-12)	7.3	.157(-11)	7.0	.354(-11)	4.7
14	.466(-13)	24.3	.141(-12)	19.2	.365(-12)	11.7	.606(-12)	11.2	.166(-11)	6.8

TABLE 19. Vibrational state-to-state reactive $\text{H}_1\text{-H}_2(v_{1-2}=11)+\text{H}_3\text{-H}_4(v_{3-4})$ rate coefficients at $T=1000\text{ K}$ (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.560(-11)	2.9	.724(-11)	2.8	.860(-11)	3.0	.106(-10)	2.8	.109(-10)	3.2
1	.828(-11)	2.4	.921(-11)	2.5	.104(-10)	2.7	.123(-10)	2.6	.119(-10)	3.1
2	.131(-10)	1.9	.129(-10)	2.1	.131(-10)	2.4	.143(-10)	2.4	.157(-10)	2.7
3	.180(-10)	1.6	.167(-10)	1.8	.171(-10)	2.1	.185(-10)	2.1	.210(-10)	2.3
4	.152(-10)	1.7	.220(-10)	1.6	.200(-10)	1.9	.245(-10)	1.8	.283(-10)	2.0
5	.173(-11)	5.2	.275(-10)	1.4	.254(-10)	1.7	.305(-10)	1.6	.378(-10)	1.7
6	.492(-12)	9.7	.180(-10)	1.8	.311(-10)	1.6	.384(-10)	1.5	.512(-10)	1.5
7	.433(-12)	10.3	.252(-11)	4.8	.362(-10)	1.4	.463(-10)	1.3	.682(-10)	1.3
8	.313(-12)	12.1	.143(-11)	6.3	.189(-10)	2.0	.541(-10)	1.2	.876(-10)	1.1
9	.317(-12)	12.0	.122(-11)	6.9	.485(-11)	4.0	.459(-10)	1.3	.108(-09)	1.0
10	.340(-12)	11.6	.863(-12)	8.2	.283(-11)	5.2	.209(-10)	2.0	.109(-09)	1.0
11	.382(-12)	11.0	.944(-12)	7.8	.230(-11)	5.8	.772(-11)	3.3	.597(-10)	1.4
12	.290(-12)	12.6	.915(-12)	7.9	.214(-11)	6.0	.537(-11)	3.9	.193(-10)	2.4
13	.244(-12)	13.7	.673(-12)	9.2	.157(-11)	7.0	.374(-11)	4.7	.992(-11)	3.4
14	.133(-12)	18.6	.247(-12)	15.2	.606(-12)	11.2	.118(-11)	8.3	.368(-11)	5.6

TABLE 20. Vibrational state-to-state reactive H₁-H₂(v₁₋₂=13)+H₃-H₄(v₃₋₄) rate coefficients at T=1000 K (H₂+H₂ reactive values)

<i>v'</i>	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.832(-11)	2.2	.940(-11)	2.4	.100(-10)	2.8	.109(-10)	3.2	.101(-10)	3.4
1	.112(-10)	1.9	.104(-10)	2.2	.108(-10)	2.7	.119(-10)	3.1	.112(-10)	3.2
2	.163(-10)	1.6	.139(-10)	1.9	.142(-10)	2.3	.157(-10)	2.7	.158(-10)	2.7
3	.250(-10)	1.3	.198(-10)	1.6	.186(-10)	2.0	.210(-10)	2.3	.211(-10)	2.3
4	.399(-10)	1.0	.280(-10)	1.4	.258(-10)	1.7	.283(-10)	2.0	.306(-10)	1.9
5	.206(-10)	1.4	.383(-10)	1.2	.337(-10)	1.5	.378(-10)	1.7	.405(-10)	1.7
6	.159(-11)	5.1	.507(-10)	1.0	.475(-10)	1.3	.512(-10)	1.5	.557(-10)	1.4
7	.101(-11)	6.4	.242(-10)	1.5	.638(-10)	1.1	.682(-10)	1.3	.726(-10)	1.2
8	.937(-12)	6.6	.371(-11)	3.8	.761(-10)	1.0	.876(-10)	1.1	.936(-10)	1.1
9	.925(-12)	6.7	.234(-11)	4.7	.370(-10)	1.4	.108(-09)	1.0	.113(-09)	1.0
10	.954(-12)	6.6	.201(-11)	5.1	.872(-11)	3.0	.109(-09)	1.0	.130(-09)	0.9
11	.921(-12)	6.7	.196(-11)	5.2	.543(-11)	3.8	.597(-10)	1.4	.137(-09)	0.9
12	.104(-11)	6.3	.186(-11)	5.3	.434(-11)	4.2	.193(-10)	2.4	.114(-09)	1.0
13	.945(-12)	6.6	.156(-11)	5.8	.354(-11)	4.7	.992(-11)	3.4	.550(-10)	1.4
14	.390(-12)	10.3	.848(-12)	7.9	.166(-11)	6.8	.368(-11)	5.6	.113(-10)	3.2

TABLE 21. Vibrational state-to-state reactive H₁-H₂(v₁₋₂=5)+H₃-H₄(v₃₋₄) rate coefficients at T=2000 K (H₂+H₂ reactive values)

<i>v'</i>	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.406(-11)	3.0	.732(-11)	2.8	.988(-11)	2.2	.131(-10)	2.2	.164(-10)	2.4
1	.267(-11)	3.7	.160(-10)	1.9	.187(-10)	1.6	.201(-10)	1.8	.216(-10)	2.1
2	.524(-12)	8.3	.118(-10)	2.2	.247(-10)	1.4	.295(-10)	1.4	.310(-10)	1.8
3	.159(-12)	15.1	.286(-11)	4.5	.210(-10)	1.5	.386(-10)	1.3	.466(-10)	1.4
4	.202(-12)	13.4	.930(-12)	7.9	.679(-11)	2.7	.361(-10)	1.3	.673(-10)	1.2
5	.133(-12)	16.4	.785(-12)	8.6	.206(-11)	4.8	.108(-10)	2.4	.470(-10)	1.4
6	.155(-12)	15.2	.703(-12)	9.1	.122(-11)	6.3	.306(-11)	4.5	.109(-10)	3.0
7	.796(-13)	21.3	.506(-12)	10.7	.117(-11)	6.4	.215(-11)	5.4	.518(-11)	4.3
8	.651(-13)	23.6	.412(-12)	11.9	.684(-12)	8.4	.190(-11)	5.7	.414(-11)	4.8
9	.470(-13)	27.7	.250(-12)	15.2	.737(-12)	8.1	.161(-11)	6.2	.331(-11)	5.4
10	.325(-13)	33.3	.261(-12)	14.9	.608(-12)	8.9	.159(-11)	6.3	.310(-11)	5.6
11			.186(-12)	17.7	.522(-12)	9.6	.134(-11)	6.8	.300(-11)	5.6
12			.250(-12)	15.2	.531(-12)	9.5	.115(-11)	7.4	.275(-11)	5.9
13			.122(-12)	21.8	.426(-12)	10.6	.945(-12)	8.1	.217(-11)	6.6
14			.756(-13)	27.7	.253(-12)	13.7	.476(-12)	11.5	.910(-12)	10.3

TABLE 22. Vibrational state-to-state reactive H₁-H₂(v₁₋₂=7)+H₃-H₄(v₃₋₄) rate coefficients at T=2000 K (H₂+H₂ reactive values)

<i>v'</i>	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.732(-11)	2.8	.101(-10)	2.6	.138(-10)	2.3	.160(-10)	2.3	.173(-10)	2.5
1	.160(-10)	1.9	.193(-10)	1.9	.188(-10)	2.0	.205(-10)	2.0	.204(-10)	2.3
2	.118(-10)	2.2	.284(-10)	1.5	.255(-10)	1.7	.269(-10)	1.7	.268(-10)	2.0
3	.286(-11)	4.5	.301(-10)	1.5	.314(-10)	1.5	.356(-10)	1.5	.367(-10)	1.7
4	.930(-12)	7.9	.119(-10)	2.4	.334(-10)	1.5	.465(-10)	1.3	.535(-10)	1.4
5	.785(-12)	8.6	.344(-11)	4.4	.225(-10)	1.8	.546(-10)	1.2	.717(-10)	1.2
6	.703(-12)	9.1	.193(-11)	5.9	.847(-11)	3.0	.437(-10)	1.4	.883(-10)	1.1
7	.506(-12)	10.7	.170(-11)	6.3	.399(-11)	4.3	.152(-10)	2.3	.559(-10)	1.4
8	.412(-12)	11.9	.129(-11)	7.2	.277(-11)	5.2	.659(-11)	3.5	.186(-10)	2.4
9	.250(-12)	15.2	.950(-12)	8.5	.230(-11)	5.7	.425(-11)	4.4	.960(-11)	3.4
10	.261(-12)	14.9	.916(-12)	8.6	.173(-11)	6.5	.367(-11)	4.7	.661(-11)	4.0
11	.186(-12)	17.7	.875(-12)	8.8	.147(-11)	7.1	.302(-11)	5.2	.518(-11)	4.6
12	.250(-12)	15.2	.692(-12)	9.9	.135(-11)	7.4	.235(-11)	5.9	.480(-11)	4.7
13	.122(-12)	21.8	.447(-12)	12.3	.806(-12)	9.6	.167(-11)	7.0	.384(-11)	5.3
14	.756(-13)	27.7	.190(-12)	18.9	.325(-12)	15.1	.781(-12)	10.2	.134(-11)	9.0

TABLE 23. Vibrational state-to-state reactive $\text{H}_1\text{-H}_2(v_{1-2}=9)+\text{H}_3\text{-H}_4(v_{3-4})$ rate coefficients at $T=2000$ K (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.988(-11)	2.2	.138(-10)	2.3	.143(-10)	2.7	.170(-10)	3.1	.157(-10)	3.2
1	.187(-10)	1.6	.188(-10)	2.0	.199(-10)	2.3	.200(-10)	2.8	.189(-10)	2.9
2	.247(-10)	1.4	.255(-10)	1.7	.270(-10)	2.0	.257(-10)	2.5	.252(-10)	2.5
3	.210(-10)	1.5	.314(-10)	1.5	.347(-10)	1.8	.340(-10)	2.2	.351(-10)	2.1
4	.679(-11)	2.7	.334(-10)	1.5	.445(-10)	1.6	.425(-10)	1.9	.463(-10)	1.9
5	.206(-11)	4.8	.225(-10)	1.8	.526(-10)	1.4	.544(-10)	1.7	.625(-10)	1.6
6	.122(-11)	6.3	.847(-11)	3.0	.517(-10)	1.4	.667(-10)	1.5	.861(-10)	1.4
7	.117(-11)	6.4	.399(-11)	4.3	.255(-10)	2.1	.751(-10)	1.5	.112(-09)	1.2
8	.684(-12)	8.4	.277(-11)	5.2	.114(-10)	3.1	.546(-10)	1.7	.120(-09)	1.1
9	.737(-12)	8.1	.230(-11)	5.7	.631(-11)	4.1	.231(-10)	2.6	.806(-10)	1.4
10	.608(-12)	8.9	.173(-11)	6.5	.461(-11)	4.8	.112(-10)	3.8	.344(-10)	2.2
11	.522(-12)	9.6	.147(-11)	7.1	.412(-11)	5.1	.770(-11)	4.6	.176(-10)	3.0
12	.531(-12)	9.5	.135(-11)	7.4	.313(-11)	5.9	.566(-11)	5.4	.110(-10)	3.8
13	.426(-12)	10.6	.806(-12)	9.6	.222(-11)	7.0	.379(-11)	6.5	.736(-11)	4.7
14	.253(-12)	13.7	.325(-12)	15.1	.640(-12)	13.0	.123(-11)	11.5	.264(-11)	7.8

TABLE 24. Vibrational state-to-state reactive $\text{H}_1\text{-H}_2(v_{1-2}=11)+\text{H}_3\text{-H}_4(v_{3-4})$ rate coefficients at $T=2000$ K (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.131(-10)	2.2	.160(-10)	2.3	.170(-10)	3.1	.186(-10)	2.9	.159(-10)	3.2
1	.201(-10)	1.8	.205(-10)	2.0	.200(-10)	2.8	.216(-10)	2.7	.186(-10)	2.9
2	.295(-10)	1.4	.269(-10)	1.7	.257(-10)	2.5	.278(-10)	2.4	.245(-10)	2.6
3	.386(-10)	1.3	.356(-10)	1.5	.340(-10)	2.2	.340(-10)	2.2	.346(-10)	2.2
4	.361(-10)	1.3	.465(-10)	1.3	.425(-10)	1.9	.451(-10)	1.9	.454(-10)	1.9
5	.108(-10)	2.4	.546(-10)	1.2	.544(-10)	1.7	.598(-10)	1.6	.609(-10)	1.6
6	.306(-11)	4.5	.437(-10)	1.4	.667(-10)	1.5	.743(-10)	1.5	.811(-10)	1.4
7	.215(-11)	5.4	.152(-10)	2.3	.751(-10)	1.5	.875(-10)	1.3	.107(-09)	1.2
8	.190(-11)	5.7	.659(-11)	3.5	.546(-10)	1.7	.987(-10)	1.3	.129(-09)	1.1
9	.161(-11)	6.2	.425(-11)	4.4	.231(-10)	2.6	.880(-10)	1.3	.149(-09)	1.0
10	.159(-11)	6.3	.367(-11)	4.7	.112(-10)	3.8	.533(-10)	1.7	.142(-09)	1.1
11	.134(-11)	6.8	.302(-11)	5.2	.770(-11)	4.6	.252(-10)	2.5	.921(-10)	1.3
12	.115(-11)	7.4	.235(-11)	5.9	.566(-11)	5.4	.128(-10)	3.6	.390(-10)	2.0
13	.945(-12)	8.1	.167(-11)	7.0	.379(-11)	6.5	.741(-11)	4.7	.174(-10)	3.1
14	.476(-12)	11.5	.781(-12)	10.2	.123(-11)	11.5	.245(-11)	8.1	.573(-11)	5.3

TABLE 25. Vibrational state-to-state reactive $\text{H}_1\text{-H}_2(v_{1-2}=13)+\text{H}_3\text{-H}_4(v_{3-4})$ rate coefficients at $T=2000$ K (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.164(-10)	2.4	.173(-10)	2.5	.157(-10)	3.2	.159(-10)	3.2	.139(-10)	3.3
1	.216(-10)	2.1	.204(-10)	2.3	.189(-10)	2.9	.186(-10)	2.9	.163(-10)	3.0
2	.310(-10)	1.8	.268(-10)	2.0	.252(-10)	2.5	.245(-10)	2.6	.210(-10)	2.7
3	.466(-10)	1.4	.367(-10)	1.7	.351(-10)	2.1	.346(-10)	2.2	.312(-10)	2.2
4	.673(-10)	1.2	.535(-10)	1.4	.463(-10)	1.9	.454(-10)	1.9	.431(-10)	1.9
5	.470(-10)	1.4	.717(-10)	1.2	.625(-10)	1.6	.609(-10)	1.6	.605(-10)	1.6
6	.109(-10)	3.0	.883(-10)	1.1	.861(-10)	1.4	.811(-10)	1.4	.770(-10)	1.4
7	.518(-11)	4.3	.559(-10)	1.4	.112(-09)	1.2	.107(-09)	1.2	.953(-10)	1.3
8	.414(-11)	4.8	.186(-10)	2.4	.120(-09)	1.1	.129(-09)	1.1	.118(-09)	1.1
9	.331(-11)	5.4	.960(-11)	3.4	.806(-10)	1.4	.149(-09)	1.0	.134(-09)	1.1
10	.310(-11)	5.6	.661(-11)	4.0	.344(-10)	2.2	.142(-09)	1.1	.151(-09)	1.0
11	.300(-11)	5.6	.518(-11)	4.6	.176(-10)	3.0	.921(-10)	1.3	.150(-09)	1.0
12	.275(-11)	5.9	.480(-11)	4.7	.110(-10)	3.8	.390(-10)	2.0	.124(-09)	1.1
13	.217(-11)	6.6	.384(-11)	5.3	.736(-11)	4.7	.174(-10)	3.1	.667(-10)	1.5
14	.910(-12)	10.3	.134(-11)	9.0	.264(-11)	7.8	.573(-11)	5.3	.167(-10)	3.0

TABLE 26. Vibrational state-to-state reactive H₁-H₂(v₁₋₂=5)+H₃-H₄(v₃₋₄) rate coefficients at T=4000 K (H₂+H₂ reactive values)

<i>v'</i>	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.180(-10)	2.1	.243(-10)	2.3	.265(-10)	2.2	.296(-10)	2.0	.314(-10)	2.2
1	.164(-10)	2.2	.348(-10)	1.9	.403(-10)	1.8	.414(-10)	1.7	.417(-10)	1.9
2	.860(-11)	3.0	.325(-10)	2.0	.488(-10)	1.6	.558(-10)	1.5	.592(-10)	1.6
3	.398(-11)	4.5	.192(-10)	2.6	.461(-10)	1.7	.663(-10)	1.3	.831(-10)	1.4
4	.217(-11)	6.0	.925(-11)	3.7	.289(-10)	2.1	.654(-10)	1.4	.104(-09)	1.2
5	.172(-11)	6.8	.484(-11)	5.1	.137(-10)	3.0	.384(-10)	1.8	.828(-10)	1.4
6	.123(-11)	8.0	.346(-11)	6.1	.742(-11)	4.1	.189(-10)	2.5	.421(-10)	1.9
7	.111(-11)	8.5	.268(-11)	6.9	.483(-11)	5.1	.112(-10)	3.3	.226(-10)	2.6
8	.857(-12)	9.6	.191(-11)	8.2	.390(-11)	5.7	.791(-11)	3.9	.128(-10)	3.4
9	.444(-12)	13.4	.168(-11)	8.7	.332(-11)	6.2	.614(-11)	4.4	.981(-11)	4.0
10	.428(-12)	13.6	.142(-11)	9.5	.323(-11)	6.3	.504(-11)	4.9	.758(-11)	4.5
11	.349(-12)	15.1	.124(-11)	10.2	.248(-11)	7.2	.415(-11)	5.4	.666(-11)	4.8
12	.317(-12)	15.8	.921(-12)	11.8	.182(-11)	8.4	.323(-11)	6.1	.488(-11)	5.6
13	.270(-12)	17.1	.690(-12)	13.6	.115(-11)	10.5	.202(-11)	7.7	.360(-11)	6.5
14	.103(-12)	27.7	.217(-12)	24.3	.294(-12)	20.9	.630(-12)	13.9	.144(-11)	10.3

TABLE 27. Vibrational state-to-state reactive H₁-H₂(v₁₋₂=7)+H₃-H₄(v₃₋₄) rate coefficients at T=4000 K (H₂+H₂ reactive values)

<i>v'</i>	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.243(-10)	2.3	.284(-10)	2.4	.296(-10)	2.1	.308(-10)	2.4	.299(-10)	2.8
1	.348(-10)	1.9	.412(-10)	2.0	.408(-10)	1.8	.412(-10)	2.1	.373(-10)	2.5
2	.325(-10)	2.0	.525(-10)	1.8	.521(-10)	1.6	.529(-10)	1.8	.516(-10)	2.1
3	.192(-10)	2.6	.540(-10)	1.7	.601(-10)	1.5	.656(-10)	1.6	.667(-10)	1.9
4	.925(-11)	3.7	.373(-10)	2.1	.651(-10)	1.4	.819(-10)	1.5	.923(-10)	1.6
5	.484(-11)	5.1	.216(-10)	2.8	.557(-10)	1.5	.873(-10)	1.4	.111(-09)	1.4
6	.346(-11)	6.1	.125(-10)	3.6	.349(-10)	2.0	.770(-10)	1.5	.125(-09)	1.3
7	.268(-11)	6.9	.761(-11)	4.6	.198(-10)	2.6	.458(-10)	2.0	.102(-09)	1.5
8	.191(-11)	8.2	.519(-11)	5.6	.120(-10)	3.3	.256(-10)	2.6	.565(-10)	2.0
9	.168(-11)	8.7	.442(-11)	6.1	.732(-11)	4.3	.170(-10)	3.2	.342(-10)	2.6
10	.142(-11)	9.5	.348(-11)	6.9	.639(-11)	4.6	.113(-10)	3.9	.203(-10)	3.4
11	.124(-11)	10.2	.236(-11)	8.3	.447(-11)	5.5	.800(-11)	4.7	.134(-10)	4.1
12	.921(-12)	11.8	.223(-11)	8.6	.349(-11)	6.2	.613(-11)	5.4	.847(-11)	5.2
13	.690(-12)	13.6	.133(-11)	11.1	.215(-11)	7.9	.340(-11)	7.2	.543(-11)	6.5
14	.217(-12)	24.3	.444(-12)	19.2	.487(-12)	16.7	.124(-11)	12.0	.177(-11)	11.4

TABLE 28. Vibrational state-to-state reactive H₁-H₂(v₁₋₂=9)+H₃-H₄(v₃₋₄) rate coefficients at T=4000 K (H₂+H₂ reactive values)

<i>v'</i>	<i>v</i> ₃₋₄ = 5		<i>v</i> ₃₋₄ = 7		<i>v</i> ₃₋₄ = 9		<i>v</i> ₃₋₄ =11		<i>v</i> ₃₋₄ =13	
0	.265(-10)	2.2	.296(-10)	2.1	.300(-10)	2.8	.299(-10)	2.8	.254(-10)	3.0
1	.403(-10)	1.8	.408(-10)	1.8	.406(-10)	2.4	.384(-10)	2.4	.310(-10)	2.7
2	.488(-10)	1.6	.521(-10)	1.6	.514(-10)	2.1	.493(-10)	2.2	.410(-10)	2.4
3	.461(-10)	1.7	.601(-10)	1.5	.657(-10)	1.9	.640(-10)	1.9	.582(-10)	2.0
4	.289(-10)	2.1	.651(-10)	1.4	.781(-10)	1.7	.759(-10)	1.7	.794(-10)	1.7
5	.137(-10)	3.0	.557(-10)	1.5	.871(-10)	1.6	.965(-10)	1.5	.105(-09)	1.5
6	.742(-11)	4.1	.349(-10)	2.0	.851(-10)	1.6	.109(-09)	1.4	.129(-09)	1.3
7	.483(-11)	5.1	.198(-10)	2.6	.643(-10)	1.9	.108(-09)	1.4	.148(-09)	1.2
8	.390(-11)	5.7	.120(-10)	3.3	.376(-10)	2.5	.897(-10)	1.6	.150(-09)	1.2
9	.332(-11)	6.2	.732(-11)	4.3	.224(-10)	3.2	.549(-10)	2.0	.117(-09)	1.4
10	.323(-11)	6.3	.639(-11)	4.6	.132(-10)	4.2	.308(-10)	2.7	.704(-10)	1.8
11	.248(-11)	7.2	.447(-11)	5.5	.932(-11)	5.0	.180(-10)	3.6	.381(-10)	2.5
12	.182(-11)	8.4	.349(-11)	6.2	.631(-11)	6.0	.107(-10)	4.6	.217(-10)	3.3
13	.115(-11)	10.5	.215(-11)	7.9	.359(-11)	8.0	.649(-11)	6.0	.111(-10)	4.5
14	.294(-12)	20.9	.487(-12)	16.7	.142(-11)	12.7	.188(-11)	11.0	.308(-11)	8.6

TABLE 29. Vibrational state-to-state reactive $H_1-H_2(v_{1-2}=11)+H_3-H_4(v_{3-4})$ rate coefficients at $T=4000$ K (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.296(-10)	2.0	.308(-10)	2.4	.299(-10)	2.8	.285(-10)	2.8	.233(-10)	3.1
1	.414(-10)	1.7	.412(-10)	2.1	.384(-10)	2.4	.355(-10)	2.5	.298(-10)	2.8
2	.558(-10)	1.5	.529(-10)	1.8	.493(-10)	2.2	.466(-10)	2.2	.381(-10)	2.5
3	.663(-10)	1.3	.656(-10)	1.6	.640(-10)	1.9	.612(-10)	1.9	.514(-10)	2.1
4	.654(-10)	1.4	.819(-10)	1.5	.759(-10)	1.7	.766(-10)	1.7	.701(-10)	1.8
5	.384(-10)	1.8	.873(-10)	1.4	.965(-10)	1.5	.931(-10)	1.6	.915(-10)	1.6
6	.189(-10)	2.5	.770(-10)	1.5	.109(-09)	1.4	.115(-09)	1.4	.114(-09)	1.4
7	.112(-10)	3.3	.458(-10)	2.0	.108(-09)	1.4	.126(-09)	1.3	.135(-09)	1.3
8	.791(-11)	3.9	.256(-10)	2.6	.897(-10)	1.6	.130(-09)	1.3	.156(-09)	1.2
9	.614(-11)	4.4	.170(-10)	3.2	.549(-10)	2.0	.115(-09)	1.4	.159(-09)	1.2
10	.504(-11)	4.9	.113(-10)	3.9	.308(-10)	2.7	.811(-10)	1.7	.146(-09)	1.2
11	.415(-11)	5.4	.800(-11)	4.7	.180(-10)	3.6	.418(-10)	2.3	.104(-09)	1.5
12	.323(-11)	6.1	.613(-11)	5.4	.107(-10)	4.6	.212(-10)	3.3	.538(-10)	2.1
13	.202(-11)	7.7	.340(-11)	7.2	.649(-11)	6.0	.119(-10)	4.4	.231(-10)	3.2
14	.630(-12)	13.9	.124(-11)	12.0	.188(-11)	11.0	.336(-11)	8.3	.677(-11)	5.8

TABLE 30. Vibrational state-to-state reactive $H_1-H_2(v_{1-2}=13)+H_3-H_4(v_{3-4})$ rate coefficients at $T=4000$ K (H_2+H_2 reactive values)

v'	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
0	.314(-10)	2.2	.299(-10)	2.8	.254(-10)	3.0	.233(-10)	3.1	.189(-10)	2.9
1	.417(-10)	1.9	.373(-10)	2.5	.310(-10)	2.7	.298(-10)	2.8	.238(-10)	2.6
2	.592(-10)	1.6	.516(-10)	2.1	.410(-10)	2.4	.381(-10)	2.5	.318(-10)	2.2
3	.831(-10)	1.4	.667(-10)	1.9	.582(-10)	2.0	.514(-10)	2.1	.421(-10)	1.9
4	.104(-09)	1.2	.923(-10)	1.6	.794(-10)	1.7	.701(-10)	1.8	.575(-10)	1.6
5	.828(-10)	1.4	.111(-09)	1.4	.105(-09)	1.5	.915(-10)	1.6	.736(-10)	1.5
6	.421(-10)	1.9	.125(-09)	1.3	.129(-09)	1.3	.114(-09)	1.4	.931(-10)	1.3
7	.226(-10)	2.6	.102(-09)	1.5	.148(-09)	1.2	.135(-09)	1.3	.111(-09)	1.2
8	.128(-10)	3.4	.565(-10)	2.0	.150(-09)	1.2	.156(-09)	1.2	.129(-09)	1.1
9	.981(-11)	4.0	.342(-10)	2.6	.117(-09)	1.4	.159(-09)	1.2	.141(-09)	1.0
10	.758(-11)	4.5	.203(-10)	3.4	.704(-10)	1.8	.146(-09)	1.2	.147(-09)	1.0
11	.666(-11)	4.8	.134(-10)	4.1	.381(-10)	2.5	.104(-09)	1.5	.139(-09)	1.1
12	.488(-11)	5.6	.847(-11)	5.2	.217(-10)	3.3	.538(-10)	2.1	.118(-09)	1.1
13	.360(-11)	6.5	.543(-11)	6.5	.111(-10)	4.5	.231(-10)	3.2	.715(-10)	1.5
14	.144(-11)	10.3	.177(-11)	11.4	.308(-11)	8.6	.677(-11)	5.8	.195(-10)	2.8

TABLE 31. Dissociative $H_1-H_2(v_{1-2})+H_3-H_4(v_{3-4})$ rate coefficients at $T=1000$ K (H_2+H_2 dissociative values)

v_{1-2}	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
5	.712(-12)	5.2	.138(-10)	1.4	.395(-10)	0.8	.862(-10)	0.7	.335(-09)	0.3
7	.138(-10)	1.4	.511(-10)	1.0	.811(-10)	0.8	.157(-09)	0.6	.438(-09)	0.3
9	.395(-10)	0.8	.811(-10)	0.8	.159(-09)	0.5	.248(-09)	0.5	.577(-09)	0.3
11	.862(-10)	0.7	.157(-09)	0.6	.248(-09)	0.5	.421(-09)	0.4	.833(-09)	0.3
13	.335(-09)	0.3	.438(-09)	0.3	.577(-09)	0.3	.833(-09)	0.3	.138(-08)	0.2

TABLE 32. Dissociative $H_1-H_2(v_{1-2})+H_3-H_4(v_{3-4})$ rate coefficients at $T=2000$ K (H_2+H_2 dissociative values)

v_{1-2}	$v_{3-4}=5$		$v_{3-4}=7$		$v_{3-4}=9$		$v_{3-4}=11$		$v_{3-4}=13$	
5	.784(-11)	2.1	.433(-10)	1.2	.103(-09)	0.7	.213(-09)	0.5	.595(-09)	0.4
7	.433(-10)	1.2	.118(-09)	0.7	.191(-09)	0.6	.350(-09)	0.5	.769(-09)	0.4
9	.103(-09)	0.7	.191(-09)	0.6	.339(-09)	0.5	.523(-09)	0.5	.970(-09)	0.4
11	.213(-09)	0.5	.350(-09)	0.5	.523(-09)	0.5	.801(-09)	0.4	.132(-08)	0.3
13	.595(-09)	0.4	.769(-09)	0.4	.970(-09)	0.4	.132(-08)	0.3	.205(-08)	0.2

TABLE 33. Dissociative H₁-H₂(v₁₋₂)+H₃-H₄(v₃₋₄) rate coefficients at T=4000 K (H₂+H₂ dissociative values)

v ₁₋₂	v ₃₋₄ =5		v ₃₋₄ =7		v ₃₋₄ =9		v ₃₋₄ =11		v ₃₋₄ =13	
5	.502(-10)	1.3	.137(-09)	1.0	.251(-09)	0.7	.435(-09)	0.5	.955(-09)	0.4
7	.137(-09)	1.0	.278(-09)	0.7	.422(-09)	0.5	.660(-09)	0.5	.121(-08)	0.4
9	.251(-09)	0.7	.422(-09)	0.5	.648(-09)	0.6	.927(-09)	0.5	.151(-08)	0.4
11	.435(-09)	0.5	.660(-09)	0.5	.927(-09)	0.5	.133(-08)	0.4	.205(-08)	0.3
13	.955(-09)	0.4	.121(-08)	0.4	.151(-08)	0.4	.205(-08)	0.3	.310(-08)	0.2

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5. References

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