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Ion-Molecule Chemistry in Titan's Ionosphere

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Abstract

We present a summary of the information available from laboratory studies of ion-molecule reactions that is relevant to the chemistry occurring in Titan's ionosphere. React ion information from the literature has been collated and we have measured many ncw reactions, including some ion-atom react ions. The sequences of ion-neutral reactions can lead to a rapid increase in ion size. How this increase may lead to aerosol production at the base of the ionosphere is briefly discussed. Laboratory observations of extremely rapid termolecular ion-neutral association reactions indicate that these association reactions arc viable contributors to the ion chemistry at the base of Titan's ionosphere.

introduction

Eight of the nine planets in our solar system have significant atmospheres. Of these four have been investigated by planetary probes and/or rockets equipped with mass spectrometers. Mass spectrometric analysis has given the atmospheric composition of the outer atmospheres of Venus, Earth, Mars and Jupiter down to below the one bar level. Of the more than 40 moons that orbit the planets of the solar system, only three (Titan, 10, and Triton) have enough atmosphere for mass spectrometric analysis during a flyby. Titan, orbiting Saturn, has by far the largest atmosphere and is a significant focus of the NASA/ESA Cassini-Huygens mission to Saturn. The expected pressure at Tian's surface is ~1000 bars. Titan with its unique blend of nitrogen and methane promises a rich chemistry with the likelihood of a number of new and interesting molecules being discovered.

The planned arrival date for the Cassini spacecraft is July 2004 and the mission has a nominal termination date of July 2008. During the tour of Saturn and its satellites the Cassini space craft will use Titan flyby's for gravity-assisted navigation, There may be up to 50 of these Titan flybys in the planned schedule. "l'he majority of the flybys will be down to altitudes of 950 km above the Titan surface and at least five of the flybys will be dedicated to in situ mass spectrometric sampling of Titan's Ionosphere. One of the twelve scientific instruments on board the space craft is the ion-Neutral Mass Spectrometer (lNMS). Its objectives are to measure the ion and neutral species composition and structure in the upper atmosphere of Titan; to study Titan atmospheric chemistry; to investigate the interaction of Titan's upper atmosphere with the magnetosphere and solar wind and to measure the mass of ions and neutral species encountered during ring plane crossings and icy satellite flybys (Cassini Mission AO).

Of particular interest to the Cassini mission and the scientific world is the descent of the Huygen's probe into "l'it an's atmosphere. A GC-MS (Gas chromatograph-mass spectrometer) is one of several instruments on the Huygen's probe and it will also perform in situ sampling of Titan's atmosphere from about 20 km down to the surface. Both the Cassini and Huygen instruments will produce, detailed mass spectrometric measurements of both the ions and the neutrals in Titan's atmosphere. To interpret these measurements, it is essential to have a detailed knowledge of the ion chemistry occuring in Titan's

atmosphere. 'I'his review of Titan's ion chemistry is therefore particular] y time] y in view of the upcoming Cassini-Huygens mission.

Interpretation of the Titan *In* Situ MS Data

A proper treatment of in *situ* mass spectrometric data of Titan's atmosphere requires more than just a knowledge of the chemical mix and density of the gas sampled, It also requires an understanding of the sequential ion chemistry that occurs in the atmosphere and that may occur at densities above. 3×10^{11} molecules cm^{-3} within the ion source of the mass spectrometer. in addition, a model of the atmospheric chemistry is required to tie the observations together. Preliminary models of the photochemical atmospheric dynamics of Titan have been presented by Yung et al, 1984, 1987; Coustenis et al, 1993, 1995 and Tourblanc et al, 1995. Preliminary models of the ionic atmospheric dynamics have been presented by Ip (1990) and Keller et al, 1992. 'l"he initial ion mass spectrum and the mass spectrum produced by electron impact ionization of neutrals in Titan's atmosphere including overlapping mass peaks, must be unraveled using a set of ion chemistry data. It is the purpose of this review to present the data relevant to Titan's ion chemistry and to point out any deficiencies in the existing data base.

Matrix of Possible Reactions

The mixing ratios of neutral species in order of increasing mass anticipated in Titan's atmosphere at 1000 km altitude are shown in Table 1. These anticipated neutral species are interpolated from the model calculations of Toublanc et al, (1995). We note that fragmentation of the neutral species by the electron impact source will produce the primary ions and several fragment ions in the mass spectrometer ion source. in addition, these same ions will be produced in the ionizing radiation field of Titan's ionosphere. Possible reactions between the ions generated from the neutrals listed in Table 1 as primary ions, with known neutral reactants gives rise to the matrix of ion-neutral chemistry shown in Table 2.. In this table, the ionic reactants are listed in the first column in some increasing order of complexity. The first row contains the major neutral components of Titan's atmosphere in order of their decreasing mixing ratios.

The cells of this matrix contain the major ionic product of the ion-neutral reaction. Where no laboratory reaction has been detected the notation NR is used in the cells. In several cases it is possible to disallow a react ion from thermochemical calculations, In these cases the cell contains the notation NR(T). Several of the cells have been filled with educated guesses, these are noted by the lighter font.

Several conclusions can be drawn about the ions generated in Titan's ionosphere from this matrix. Almost all of the ions in the first column are unreactive with the. major neutral component of Titan, molecular nitrogen. The exceptions are H_2^+, H_3^+ and NH_4^+. These three ions will be in very small steady state abundances at all altitudes. They will rapidly be converted to N_2H^+, which has as its principal loss process, a rapid proton transfer reaction with the neutral hydrocarbons.

After N_2, the next most abundant neutrals are the hydrocarbons CH_4, C_2H_2 and C_2H_4. It is quite apparent from the columns in Table 2 corresponding to these three neutrals, that the majority of ions generated in the Titan ionosphere are reactive with them, Each reactive collision increases the number of carbons in the product ion by either one or two. There are thus efficient pathways via ion molecule reactions to generate complex molecular ions containing many atoms. The processes opposing the progress to increasing molecular complexity by an ion-molecule mechanism are electron recombination, photodissociation and their ultimate removal via aerosol formation followed by "rain-out".

ions that are unreactive in Titan's atmosphere will accumulate in abundance until they achieve equilibrium with their major loss process which may be electron ion recombination. Table 2 shows unreactive ions in this category to include $c\text{-}C_3H_3^+$, and to a lesser extent, H_3O^+ and $HCNH^+$. $c\text{-}C_3H_3^+$ is known to undergo reaction with diacetylene, C_4H_2, but additional loss processes may be uncover-cd once more laboratory measurements have been made. Although H_3O^+ undergoes only a slow endothermic proton transfer reaction with C_2H_4, it does undergo rapid exothermic proton transfer with HCN and HC_3N. The $HCNH^+$ ion dots not exhibit rapid bimolecular reactions with N_2 or the more abundant hydrocarbons but it does exhibit fast reactions with H_2O and HC_3N. Each of these ions however, may

undergo efficient termolecular association reactions at higher pressures and very few of these termolecular processes have been evaluated in the laboratory.

From a survey of the cells in Table 2 it can be seen that there are many other ions that will be generated in Titan's ionosphere besides the ions listed in the first column of Table 2. The additional ions anticipated in Titan's ionosphere that are not represented as reactant ions in Table 2 include: $C_2H_7^+$, $C_3H_6^+$, $C_3H_9^+$, $C_4H_4^+$, $C_4H_9^+$, $C_5H_2^+$, $C_5H_3^+$, $C_5H_7^+$, $C_6H_2^+$, $C_6H_4^+$, $C_6H_5^+$, $C_6H_7^+$, $C_6H_{12}^+$, $C_7H_5^+$, $C_7H_7^+$, NH_3^+, C_2N^+, HC_2N^+, $H_2C_2N^+$, $H_4C_2N^+$, $H_3C_3N^+$, $H_2C_4N^+$, $H_6C_4N^+$, $H_3C_5N^+$, $H_5C_5N^+$, $H_3C_7N^+$, CO+, HCO^+, CH_2OH^+, HNC^+, HNO^+ and NCO^+. Further, the following ions are formed as secondary ions from the reactions of the primary ions with the atmospheric neutrals on Titan's atmosphere. These ions are also not included as reactants in Table 2. They are: C_3^+, $C_3H_8^+$, C_4H^+, $C_4H_6^+$, $C_4H_8^+$, C_5H^+, $C_5H_4^+$, $C_5H_9^+$, $C_6H_3^+$, $C_8H_2^+$, $C_8H_3^+$, $C_8H_4^+$, $C_8H_5^+$, $C_8H_6^+$, $C_8H_7^+$, $C_9H_7^+$, $C_9H_8^+$, $C_9H_9^+$, $C_{10}H_8^+$, $C_{10}H_9^+$, $C_{10}H_{11}^+$, $C_{11}H_9^+$, NH_4^+, $CHNH_2^+$, $CH_2NH_2^+$, CH_2CNH^+, $CH_2CHNH_2^+$, CH_3NCH^+, C_3N^+, $C_2H_3CN^+$, $C_2H_3CNH^+$, $H_5C_3N^+$, $C_2H_5CNH^+$, C_4N^+, HC_4N^+, HC_5N^+, HC_5NH^+, $C_5H_4N^+$, $C_7H_5N^+$, $C_2N_2^+$, $HC_2N_2^+$, $C_4N_2^+$, $C_4N_4^+$, $HC_5N_2^+$, $(C_2H_3CN)_2^+$, $(C_2H_3CN)_2H^+$, $HC_6N_2^+$, $H_2C_6N_2^+$, H_2CO^+, CH_3O^+, CH_3CO^+, $CHCCO^+$, NO' and $HNCO^+$.

Table of Ion-molecule Reactions

The atmospheres of both Titan and Earth are N_2-based and they make for some interesting comparisons. It is the presence of hydrocarbons in Titan's atmosphere that leads to an extensive and complex ion chemistry that is absent from terrestrial atmospheric ion chemistry. Table 3, attached to this paper, includes all of the ion-molecule reactions measured thus far that have some relevance to Titan ion chemistry. 'l'able 3 lists the reactant ion and neutral along with the identified product channels, branching rat ios, rate coefficients and a reference to where the work was published, The rate coefficients are "best"

values, many of which were taken from reference b at the end of the Table. Where a new reaction (not in reference b) has several new measurements, the data cited represents new "best" values. "l'he reference numbers used in Table 3 are attached at the end of the Table with a citation to the published research and are the same numbers used in a data base that is presently being maintained by one of the authors (VGA).

The authors have also taken the liberty to include in Table 3, several reactions that may be deduced to show no reaction cm the basis of thermochemical considerate ions. These non-react ions have been noted as reference numbers c and f

Termolecular Reactions

Up to this point we have tacitly assumed that bimolecular ion-molecule reactions are the main cent ributors to Titan's ion chemistry. In the terrestrial ionospheric chemistry, this assumption is generall y valid, with the main exception being electron attachment to 0_2 in the D region which is a termolecular process and is the process corresponding to transfer of the negative ion charge carrier from electrons to O_2^- (Ferguson et al. 1979). In contrast to Earth's atmosphere which is mainly composed of diatomic and to a lesser extent triatomic gases, Titan's atmosphere has significant contributions from pol yatomic neutrals. The presence of polyatomic molecules means that termolecular ion-molecule processes become more. important than in the earth's ionosphere as there are now more energy modes in the initial ion-molecule complex in which the reaction energy may be redistributed. The increased number of degrees of freedom in ion molecule collision complexes result in collision complex lifetimes that are long enough for collisional stabilization to occur via a collision with the bath N_2 molecules,

There is now a substantial body of laboratory evidence supporting the case for considering termolecular ion-molecule reactions in models at the base of Titan's ionosphere, i.e. from about 850 km down to the surface. Ions that are unreactive with N_2 via bimolecular reactions can form adducts via termolecular channels. Table 3 shows that candidate ions in this category include CH_2^+, CH_3^+, N^+, N_2^+, N_2H^+ and H_2O^+. (The termolecular processes in Table 3 are noted by an M over the reaction arrow.) In

these cases, the reaction rate coefficients listed are for the termolecular process and have units of $cm^6 s^{-1}$. In several cases there are no measured termolecular reaction rate coefficients, but we have listed the effective bimolecular reaction rate coefficient for the saturated termolecular reaction. It is expected that other ions will have the same behaviour, but they have not as yet been tested in the laboratory. Studies in our laboratory have found termolecular ion-molecule association reactions (with N_2 as the stabilizing gas) at room temperature having reaction rate coefficients which are greater than 10^{-23} cm^6 S-l (McEwan et al. (1989) and Smith et al. (1993)). Association rate coefficients this large can compete effectively with fast bimolecular chemical reactions at number densities as low as 3 x 1011 molecules cm^{-3} (i .e. up to the 850 km altitude region of Titan). The lower temperatures of Titan's atmosphere will further enhance termolecular association reactions over bimolecular.

Ion-molecule Reaction Sequences in Titan's Ionosphere

A reaction sequence flow chart can be developed showing the processing of the ionic species through their ion-molecule reaction pathways. A flow chart showing the major ion-molecule reaction sequences from the reactant ions used in Table 2 is given in Figure 1. 'he only ions not included in this flow chart are the minor ions: $C_3H_7^+$, $C_4H_2^+$, $C_4H_3^+$, and NH_2^+. The ionic species are enclosed by ellipses. 'l'he *major* pathways are indicated by solid arrows and *minor* channels by dashed arrows, The reactant neutrals arc printed near the tail of the arrows. No matter how an ion is produced, it will react by the reaction sequence. shown. The major channels are the result of reactions with the *major* neutral components of Titan's atmosphere, viz: N_2, CH_4, C_2,112 or C_2H_4. 'l'he reaction pathways can be followed and the ions: CH_5^+, c-$C_3H_3^+$, and $C_3H_5^+$ are found to be have rapid pathways of formation and slow pathways of reactive loss. These three ions are expected to be bottle necks and have the major concentrations in Titan's ionosphere. H_2CN^+ is unreactive with the major neutrals of the atmosphere and its reaction with HC_3N has been included as a minor sequence only. It is surprising that so much H_2CN^+ is projected to be present in the lower ionosphere. The ion chemistry presented shows that the major production channel for this ion

is through the di ssociat ivel y ionized nitrogen, the N^+ ion reacts with CH_4 to produce both HCN^+ and H_2CN^+ from this reaction in a collective 43% of the collisions. The principle source of ions is the photoionization of N_2 producing N_2^+ and N^+ in a ratio of about 6 to 1. Once the H_2CN^+ is formed there are only very slow loss processes. It will be very important to discover any unknown reaction pathways of the H_2CN^+ ion.

The reaction channels given in Figure 1 represent the most reactive channels at the time of this publication. We note that many reactions of relevance to Titan's ion chemistry have not yet been measured and cannot therefore be included in Figure 1. Further, no attempt has been made to distinguish between isomeric structures of the ions. Several stable structures exist for almost all ions containing three or more atoms and there has been little work done thus far in establishing these structures.

Figure 1 demonstrates the progression in molecular complexity anticipated after just a few reactions. Ions containing 1-3 atoms are efficiently converted into ions containing many atoms. Several flow sequences end in question marks, These have been included to signify the end of laboratory data currentl y available. Although the chains arc shown ending with the ions $C_5H_3^+$, $C_{11}H_9^+$, $H_2C_2N^+$ and $H_3C_5N^+$, it is not anticipated that these ions are terminal ions. Rather they most probably will react further.

The translation of the sequences shown in Figure 1 to the ionosphere of Titan is not the subject of this paper. It is the domain of the modeller to convert the laboratory data and reaction rate coefficients reported here into ionisation rates and ion densities. Most current models of Titan's ionosphere. show H_2CN^+ to be the major ion above 700 km (Keller et al. (1992)). We note however, that none of the models thus far allow for termolecular association reactions as significant loss processes for relatively unreactive ions such as H_2CN^+ at the base of the ionosphere. For an estimated neutral density at 700 km of 10]2 molecules cm^{-3}, any termolecular process with a rate coefficient of k >10-23 $cm^6 s^{-1}$ would need to be considered. No termolecular reactions of $HCNH^+$ with rate coefficients this large have yet been

identified in the laboratory. However slower termolecular associations of HCN} I^+ with the hydrocarbons C_2H_2 and C_2H_4 have been established (Herbst et al. (1989).

$$HCNH^+ + C_2H_2 + M \rightarrow H_4C_3N^+ + M$$

$$k = 1.S \times 10^{-28} cm^6 s^{-1} \text{ at } 210 \text{ K } (M = He)$$

$$HCNH^+ + C_2H_4 + M \rightarrow H_6C_3N^+ -t M$$

$$k = 1.8 \times 10^{-26} cm^6 s^{-1} \text{ at } 21 \text{ OK}; k > 2 \times 10^{-26} cm^6 s^{-1} \text{ at } 80 \text{ K } (M = He)$$

Unsaturated hydrocarbon ions also show a marked propensity for association, We have measured room temperature rate coefficients as large as k = 2.9 x 10-23 $cm^6 s^{-1}$ (M = N_2) for the termolecular association between $C_4H_2^+$ and C_2H_2 (Anicich et al. (1990)).

$$C_4H_2^+ -t C_2H_2 + M \rightarrow C_6H_4^+ + M$$

It is thus possible that rapid association reaction sequences leading to complex molecular ion formation in relatively few steps may lead to ions sufficiently large to act as nucleation centers for small droplets at the base of Titan's ionosphere. Clearly further laboratory work needs to be dorm in this area.

Conclusion

It is anticipated that Titan's lower ionosphere will be a bath of quite exotic ions and neutrals compared to the ionosphere of Earth. The presence of these exotic species is a consequence of the unreactivity of almost all ions formed in the primary ionization processes, with the major component of Titan's atmosphere, molecular nitrogen. The hydrocarbons CH_4, C_2H_2, and C_2H_4, although comprising only about 7% of the bulk atmospheric constituents (compared to 20% for 0_2 on Earth), exert an influence on the outcome of ion chemistry processing that far out weighs their numerical number densities. These

hydrocarbon neutrals are reactive with most of the expected primary ions with the exception of three ions: CH_5^+, c-$C_3H_3^+$, and $C_3H_5^+$. These three ions, because of their low reactivity, along with H_2CN^+ and 1130+, arc expected to become the prominent ions of the ionosphere.

At the bottom of the ionosphere (ie around the 850 km level) termolecular ion reactions are expected to become increasingly prominent in the ion neutral rection sequence. Both bimolecular and termolecular reactions therefore occur together. At these lower altitudes, many reactions occur before the ion is final] y removed by neutralisation by ion electron recombination. In this region of the atmosphere, there is a rapid progression in molecular complexity as a result of the ion chemistry. The laboratory studies summarised in this review show that likely complex ions in the intermediate region will include $C_5H_3^+$, $C_{11}H_9^+$, 1 $I_2C_2N^+$ and $H_3C_5N^+$. However we note that the laboratory studies of these ions with the major at mospheric constituents on Titan have not yet been made. Further studies are needed to establish the next sequences of ion - molecule complexity before the onset of aerosol formation.

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Table 1

Mass peaks anticipated in Titan's atmosphere at 1000 km altitude interpolated from the model atmosphere of Toublanc et al. (1995)

Mass	Species	Mixing Ratio @1000 km
1	H	7E-4
2	H_2	4E-3
14	$^1CH_2$	1E-8
14	$^3CH_2$	7E-6
15	CH_3	4E-4
16	CH_4	6E-2
18	H_2O	1E-5
26	C_2H_2	4E-3
27	HCN	4E-4
28	N_2	9.4E-1
28	C_2H_4	4E-3
28	H_2CN	2E-6
28	CO	3E-6
30	C_2H_6	1 E-5
30	CH_2O	2E-7
32	CH_3OH	2E-7
38	C_3H_2	3E-5
39	HC_2N	2E-5
40	C_3H_4	1 E-5
41	CH_3CN	8E-9
42	C_3H_6	1 E-6
42	CH_2CO	3E-13
44	C_3H_8	7E-6
44	CO_2	6E- 11
50	C_4H_2	3E-6
50	C_3N	3E-8
51	HC_3N	1 E-5
52	H_2C_3N	1E-16
52	C_2N_2	2E-7
74	C_6H_2	1 E-7
76	C_4N_2	3E-5
98	C_8H_2	2E-8

Table 2. Major Ionic Products of the Ions and Neutrals in Titan's Atmosphere

	N_2	CH_4	C_2H_2	C_2H_4	H_2	N	H	CH_3	HCN	C_3H_2	C_4N_2	HC_2N	C_2H_6	C_3H_4	H_2O	HC_3N	CH_2	C_3H_8	C_4H_2	co	H_2CN	C_3H_6
H^+	NR(T)	CH_3^+	$C_2H_2^+$	$C_2H_4^+$	NR	NR(T)	NR		HCN^+				$C_2H_5^+$		H_2O^+							
H_2^+	N_2H^+	CH_3^+	$C_2H_2^+$	$C_2H_4^+$	H_3^+		H^+						$C_2H_4^+$		H_3O^+					HCO^+		
H_3^+	N_2H^+	CH_5^+	$C_2H_3^+$	$C_2H_3^+$	NR	NH_2^+	NR(T)		H_2CN^+				$C_2H_5^+$		H_3O^+	$H_2C_3N^+$			$C_4H_3^+$	HCO'		
C^+	NR	$C_2H_3^+$	C_3H^+	$C_3H_3^+$	CH^+	NR(T)	NR(T)		C_2N^+				$C_3H_3^+$		HCO^+	C_3H^+		$C_2H_3^+$		NR		
CH^+	NR	$C_2H_3^+$	$C_3H_2^+$	$C_3H_3^+$	CH_2^+	CN^+	c+		H_2CN^+						H_3O^+					HCO^+		
CH_2^+	NR(T)	$C_2H_4^+$	$C_3H_3^+$	$C_3H_4^+$	CH_3^+	HCN^+			$H_2C_2N^+$						CH_2OH^+	$H_2C_3N^+$				NR		
CH_3^+	NR	$C_2H_5^+$	$C_3H_3^+$	$C_3H_5^+$	NR	H_2CN^+	NR		$H_4C_2N^+$				$C_2H_5^+$		NR	$C_3H_3^+$			$C_3H_3^+$	NR		
CH_4^+	NR	CH_5^+	$C_2H_2^+$	$C_2H_4^+$	CH_5^+		NR		H_2CN^+				$C_2H_4^+$		H_3O^+	$H_2C_3N^+$				HCO^+		
CH_5^+	NR(T)	NR	$C_2H_3^+$	$C_2H_5^+$	NR	NR	CH_4^+						$C_2H_7^+$		H_3O^+	$H_2C_3N^+$				HCO^+		
C_2H^+	NR	$C_3H_3^+$	$C_4H_2^+$	$C_2H_3^+$	$C_2H_2^+$	CH^+			HC_3N^+							$H_2C_3N^+$						
$C_2H_2^+$	NR	$C_3H_5^+$	$C_4H_3^+$	$C_3H_3^+$	$C_2H_3^+$	HC_2N^+	NR		H_2CN^+				$C_3H_5^+$		H_3O^+	$H_3C_5N^+$			$C_4H_2^+$			
$C_2H_3^+$	NR(T)	$C_3H_5^+$	$C_4H_3^+$	$C_2H_5^+$	NR	HC_2N^+	$C_2H_2^+$		H_2CN^+				$C_2H_5^+$		H_3O^+	$H_2C_3N^+$						
$C_2H_4^+$	NR(T)	NR	$C_3H_3^+$	$C_3H_5^+$	NR		$C_2H_3^+$		NR				$C_3H_7^+$		NR	$H_2C_3N^+$						
$C_2H_5^+$	NR	$C_3H_7^+$	$C_4H_5^+$	$C_3H_5^+$	NR	NR	$C_2H_4^+$		H_2CN^+				$C_4H_9^+$		H_3O^+	$H_2C_3N^+$		$C_3H_7^+$				
$C_2H_6^+$	NR	NR	$C_3H_5^+$	$C_2H_4^+$	NR		$C_2H_5^+$		H_2CN^+				$C_3H_9^+$		H_3O^+							
C_3H^+	NR	$C_2H_3^+$	$C_5H_2^+$	$C_3H_3^+$	$C_3H_3^+$		NR		$H_2C_4N^+$					$C_4H_3^+$	HCO^+	$H_2C_6N^+$			$C_5H_2^+$			
$C_3H_2^+$	NR		$C_5H_3^+$		NR		C_3H^+							$C_4H_4^+$								
c-$C_3H_3^+$	NR	NR	NR	NR	NR	NR	NR		NR				NR	NR		NR			$C_5H_3^+$	NR		
$C_3H_4^+$	NR		$C_5H_5^+$		NR		$C_3H_3^+$		NR					$C_6H_7^+$								
$C_3H_5^+$	NR	NR	$C_5H_5^+$	$C_5H_7^+$	NR	$C_2H_4^+$	$C_2H_3^+$		$H_6C_4N^+$				NR			$H_2C_3N^+$						$C_6H_{12}^+$
$C_3H_7^+$	NR		$C_5H_7^+$		NR	NR	$C_3H_6^+$															
$C_4H_2^+$	\-R		$C_6H_4^+$		NR				NR					$C_7H_5^+$		$H_3C_7N^+$			$C_6H_2^+$	NR		
$C_4H_3^+$	NR		$C_6H_5^+$		NR		$C_4H_2^+$		NR					$C_5H_5^+$					$C_6H_5^+$	NR		
$C_4H_5^+$	NR		$C_6H_7^+$		NR									$C_7H_7^+$					$C_6H_5^+$			
$C_4H_7^+$	NR		$C_6H_7^+$		NR	NR																
$C_5H_5^+$	NR		$C_7H_7^+$		NR									$C_6H_7^+$					$C_7H_5^+$			
N^+	NR	CH_3^+	$C_2H_2^+$	$C_2H_4^+$	NH^+	NR(T)	NR(T)		HCN^+				$C_2H_5^+$		H_2O^+	HC_3N^+				co+		
NH^+	N_2H^+	H_2CN^+		$C_2H_4^+$	NH_2^+										H_3O^+					NCO^+		
NH_2^+	NR	NH_3^+		$C_2H_4^+$	NH_3^+										H_3O^+					NR		
N_2^+	NR	CH_3^+	N_2H^+	$C_2H_3^+$	N_2H^+	NR	NR		HCN^+				$C_2H_5^+$		H_2O^+	HC_3N^+				co+		
N_2H^+	NR	CH_5^+	$C_2H_3^+$	$C_2H_5^+$	H_3^+		NR		H_2CN^+				$C_2H_5^+$		H30"	$H_2C_3N^+$			$C_4H_3^+$	HCO^+		
H_2O^+	NR	H_3O^+		$C_2H_5^+$	H_3O^+	HNO^+			H_3O^+				H_3O^+		H_3O^+					HCO^+		
H_3O^+	NR(T)	NR(T)	NR(T)	$C_2H_5^+$	NR	NR	NR(T)		H_2CN^+				NR(T)		NR	$H_2C_3N^+$		NR(T)	$C_4H_3^+$	NR(T)		NR(T)
CN^+	NR	CH_3^+	$C_2H_2^+$	$C_2H_4^+$	HCN^+	N_2^+	H'		HCN^+				$C_2H_4^+$		HCN^+	HC_3N^+			$C_4H_2^+$	co'		
HCN^+	NR	H_2CN^+	$C_2H_2^+$		H_2CN^+		H^+		H_2CN^+						H_3O^+	$H_2C_3N^+$				HNC^+		
H_2CN^+	NR	NR	NR	NR	NR	NR	NR		NR				NR		H_3O^+	$H_2C_3N^+$			C4H3'			
$H_2C_3N^+$	NR		$H_3C_5N^+$	$H_5C_5N^+$	NR		NR									NR				NR		
	N_2	CH_4	C_2H_2	C_2H_4	H_2	N	H	CH_3	HCN	C_3H_2	C_4N_2	HC_2N	C_2H_6	C_3H_4	H_2O	HC_3S	CH_2	C_3H_8	C_4H_2	co	H_2CN	C_3H_6

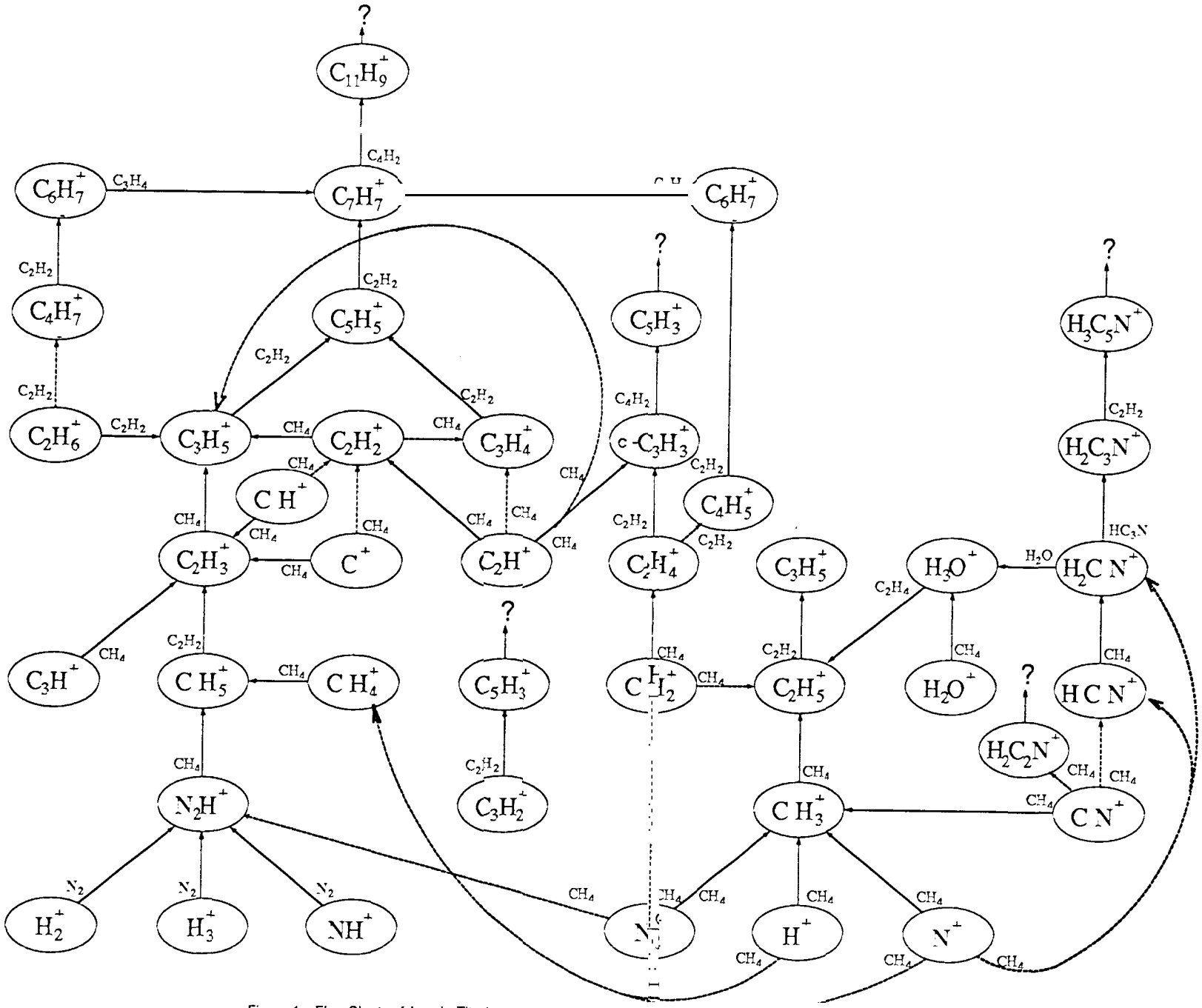

Figure 1 - Flow Chart of Ions in Titan's

Solid Lines are Major pathways ------ Broken Lines are Minor pathways

Table 3 (cont.)
Ion-Molecule Rent.tiom Relavent to Titan's Atmosphere

Reactions					Br. Ratio	Rate Coefficient*	Reference
H^+	+ H_2	---→	No Reaction			$<1.00 \times 10^{-12}$	7107
		—M→	Adduct			3.00×10^{-29} (M = H_2)	8632
H^+	+ HD	)	D^+	+ H_2	1.00	$1.70 \times 10^{-10} \pm 20\%$	8109
H^+	+ D_2	›	D^+	+ HD	1.00	$3.60 \times 10^{-10} \pm 20\%$	b
D^+	+ H_2	- ›	H^+	+ HD	1.00	1.4 OX1O-9 *20%	b
D^+	+ HD	---→	H^+	+ D_2	1.00	9.50×10^{-10} *209o	8109
D^+	+ D_2	—M)	Adduct			3.00×10^{-29} (M= D_2)	8632
H^+	+ CH_4	- ›	CH_3^+	+ H_2	0.82	4.15 X1 O-9 ± 10%	b
			CH_4^+	+ H	0.18		
D^+	+ CH_4	)	CH_3^+	+ HD	0.57	3.50×10^{-9} *1O%	8421
			CH_2D^+	+ H_2	0.21		
			CH_4^+	+ D	0.21		
H^+	+ C_2H_6	---→	$C_2H_3^+$	+ H_2 -1 H_2		3.9 OX1O-9 ± 20%	8117
			$C_2H_4^+$	+ H_2 + H			
			$C_2H_5^+$	+ H_2			
H^+	+ N	-›	No Reaction			$<1.00 \times 10^{-11}$	c
H^+	+ N_2	)	No Reaction			$<1.00 \times 10^{-11}$	c
H^+	+ H_2O	)	H_2O^+	+ H	1.00	8.2 OX1O-9 ± 10%	7401
H^+	+ HCN	›	HCN^+	+ H	1.00	l.lox Io-8 ±20%	b
H_2^+	+ 11	- ›	H^+	+ H_2	1.00	$6.40 \times 10^{-10} \pm 20\%$	7901
D_2^+	+ D	---→	D^+	+ D_2	1.00	$5.00 \times 10^{-10} \pm$ IO%	7901
H_2^+	+ H_2	- ›	H_3^+	+ H	1.00	2.00 X10-9 ± 10%	b
H_2^+	+ D_2	- ›	H_2D^+	+ D		3.2 OX1O-9 ± 20%	7212
			HD_2^+	+ H			
D_2^+	+ H_2	- ›	H_2D^+	+ D		3. OOX1O-9 *20%	7212
			HD_2^+	+ H			
D_2^+	+ D_2	- ›	D_3^+	+ D	1.00	1.60x 10-9 ±5%	7212
H_2^+	+ CH_4	- ›	CH_3^+	+ H_2 + 11	0.60	3.8 OX1O-9 ± 10%	7503
			CH_4^+	+ H_2	0.37		
			CH_5^+	+ H	<0.03		
H_2^+	+ C_2H_2		$C_2H_2^+$	+ H_2	0.91	5.3 OX1O-9 *IO%	7503
			$C_2H_3^+$	+ H	0.09		
H_2^+	+ C_2H_4		$C_2H_2^+$	+ H_2 + H_2	0.18	4.9 OX1O-9 ± 10%	7503
			$C_2H_3^+$	+ H_2 + H	0.37		
			$C_2H_4^+$	+ H_2	0.45		
H_2^+	+ C_2H_6	–)	$C_2H_2^+$	+ H_2 + H_2 + 1120.04		4.90 $\times 10^{-9}$ ± 10%	7503
			$C_2H_3^+$	+ H_2 + H_2 + H	0.14		
			$C_2H_4^+$	+ H_2 + H_2	0.48		
			$C_2H_5^+$	+ H_2 + H	0.28		
			$C_2H_6^+$	+ H_2	0.06		

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
H_2^+	+ N_2	→ N_2H^+	+ H	1.00	2.00 X10-9 ±10%	b
D_2^+	+ N_2	→ N_2D^+	+ D	1.00	1.61x 10-9 ±10%	6907
H_2^+	+ H_2O	→ H_2O^+ H_3O^+	+ H_2 + H	0.53 0.47	7.3 OX1O-9±10%	7503
H_2^+	+ CO	→ HCO^+ CO^+	+ 11 + H_2	0.77 0.23	2.90x I O-9 ± 10%	b
H_3^+	+ H	→ No Reaction			<1.00x10^{-11}	c
H_3^+	+ H_2	$\xrightarrow{M}$ Adduct			9. OOX1O-3O (M = 11,)	8632
H_3^+	+ HD	→ H_2D^+	+ H_2	1.00	I.1OX1O-9 ±20%	8105
H_2D^+	+ H_2	→ H_3^+	-1 HD	1.00	5.60x10^{-10}±20%	8105
H_2D^+	+ HD	→ HD_2^+	+ H_2	1.00	2.60x10^{-10}±10%	7611
HD_2^+	+ HD	→ H_2D^+	+ D_2	1.00	3.50x10^{-10}±10%	7611
D_3^+	+ H_2	→ Products		1.00	4.00x10^{-10}±20%	7615
D_3^+	+ D_2	$\xrightarrow{M}$ Adduct			1.47x 10^{-28} (M= 1),)	8632
H_3^+	+ CH_4	→ CH_5^+	+ H_2	1.00	2.40x 10^{-9} ±20%	b
D_3^+	+ CH_4	→ CH_4D^+	+ D_2	>0.98	2.4ox1o-9 ±25%	7501
H_3^+	-1 C_2H_2	→ $C_2H_3^+$	+ H_2	1.00	3.2 OX1O-9±25%	b
H_3^+	+ C_2H_4	→ $C_2H_3^+$ $C_2H_5^+$	+ H_2 + H_2 + H_2	0,70 0.30	2.9 OX1O-9±20%	b
H_3^+	+ C_2H_6	→ $C_2H_5^+$	+ H_2 + H_2	1.00	2.9 OX1O-9±25%	b
H_3^+	+ C_4H_2	→ $C_4H_3^+$	+ H_2	1.00	2.6 OX1O-9±30%	8645
H_3^+	+ N	→ NH_2^+	+ 11	1.00	-I. OOX1O-9	e, 7714
H_3^+	+ N_2	→ N_2H^+	+ H_2	1.00	1.86x 10-9 ±10%	b
D_3^+	+ N_2	→ N_2D^+	+ D_2	1.00	7.49 X1 O-10*1O%	6907
H_3^+	+ }120	→ H_3O^+	+ H_2	1.00	5.3 OX1O-9±25%	b
H_3^+	+ CO	→ HCO^+ HOC^+	-1 H_2 + H_2	0.94 0.06	1,85x 1o-9 ±25%	b
H_3^+	+ HCN	→ $HCNH^+$	+ H_2	1.00	7.50 x10^{-9}±10%	b
H_3^+	+ CH_3CN	→ CH_3CNH^+	+ H_2	1.00	8.90x 10^{-9} *25%	b
H_3^+	+ HC_3N	→ $CHCCNH^+$	+ H_2	1.00	9.80x 10^{-9}±30%	b
H_3^+	+ C_2N_2	→ $HC_2N_2^+$	+ H_2	1.00	2.80x 10^{-9}±25%	b
C^+	+ H	→ No Reaction			<1.00x10^{-11}	c

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Rea				Br. Ratio	Rate Coefficient*	Reference
C^+	+ H_2	→	CH^+ + H	1.00	$1.20 \times 10^{-16} \pm 75\%$	b
		$\xrightarrow{M}$	Products		2.10×10^{-29} (M = He)	
C^+	+ HD	→	CH^+ + D	0.17	1.2ox1o-16i75%	8607
			CD^+ + H	0.83		
C^+	+ D_2	→	CD^+ + D	1.00	$2.30 \times 10^{-17} \pm 75\%$	b
		$\xrightarrow{M}$	Products		2.00×10^{-29} (M = He)	
C^+	+ CH_4	→	$C_2H_2^+$ + H_2	0.28	1.30X 0^{-9} ±10%	b
			$C_2H_3^+$ + H	0.72		
C^+	+ C_2H_2	→	C_3H^+ + H	1.00	2.63x 0^{-9} ±10%	b
C^+	+ C2114	→	$C_2H_3^+$ + CH	0.08	1.50X 0^{-9} ±30%	b
			$C_2H_4^+$ + C	0.15		
			C_3H^+ + H_2 + H	0.05		
			$C_3H_2^+$ + H_2	0.29		
			$C_3H_3^+$ + H	0.42		
C^+	+ C_2H_6	→	$C_2H_2^+$ + CH_4	0.05	I.65x1o-9 ±30%	b
			$C_2H_3^+$ + CH3	0.30		
			$C_2H_4^+$ + CH_2	0.07		
			$C_2H_5^+$ -r CH	0.14		
			$C_3H_2^+$ + H_2 -1 H_2	0.01		
			$C_3H_3^+$ + H_2 + 11	0.43		
C^+	t c3118	→	$C_2H_3^+$ + C_2H_5	0.35	1.85×10^{-9} ±30%	8309, 8207
			$C_3H_3^+$ + CH_4 + H_2	0.20		
			i-$C_3H_7^+$ + cl l_2	0.30		
			$C_3H_8^+$ + C	0.10		
			$C_4H_5^+$ + H_2 + }1	0.05		
C^+	+ C_4H_2	→	C_5H^+ + 11	0.50	2,90x 10^{-9} ±30%	8645
			$C_4H_2^+$ + C	0.45		
			C_3H^+ + C_2H	0.05		
C^+	+ N	→	No Reaction		$<1.00 \times 10^{-11}$	c
C^+	+ N_2	→	No Reaction		$<2.00 \times 10^{-14}$	b
C^+	+ H_2O	→	H_2O^+ + C	0.10	2.4 OX1O-9±15%	b
			HCO^+ + 11	0.90		
C^+	•r HCN	→	C_2N^+ + H	1.00	2.95x o-9 *15%	b
C^+	+ CH_3CN	→	Products	1.00	5.60x 0^{-9} ±20%	9015
C^+	+ C_2N_2	→	CCN^+ + CN	0.11	1.90X 0^{-9} ±30%	b
			CNC^+ + CN	0.89		
C^+	+ HC_3N	→	C_3^+ + HCN	0.05	5.5 OX1O-9±20%	b
			C_3H^+ + CN	0.70		
			C_2N^+ + C_2H	0.02		
			C_4N^+ + H	0.23		
C^+	+ CO	→	No Reaction		<5.00X 10^{-13}	b
CH^+	-r H	→	C^+ + H_2	1.00	7.50X 0^{-10}±30%	8403
CH^+	+ H_2	->	CH_2^+ + H	1.00	1.20X 0^{-9} ±15%	b

Table 3 (rent)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
CH^+	+ CH_4	→ $C_2H_2^+$	+ H_2 + H	0.11	1.3 OX1O-9 *20%	b
		$C_2H_3^+$	+ H_2	0.84		
		$C_2H_4^+$	+ H	0.05		
CH^+	+ C_2H_2	→ $C_3H_2^+$	+ H	1.00	2.40x 10^{-9} ● IO%	8624
CH^+	+ N	→ CN^+	+ H	1.00	1.90x10^{-10}±50%	b
		H^+	+ CN	0.00		
CH^+	+ N_2	→ No Reaction			<1.00x10^{-11}	c
		$\xrightarrow{M}$ Adduct			5.3ox1o-29 (M = lie)	8632
CH^+	+ H_2O	→ H_3O^+	+ C	>0.50	2.9 OX1O-9±20%	7705
		HCO^+	+ H_2			
		H_2CO^+	+ H			
c11+	+ HCN	→ $HCNH^+$	+ C	0.75	2.80x 10-9 ±15%	b
		C_2N^+	+ H_2	0.15		
		$CHCN^+$	+ H	0.10		
CH^+	+ CO	→ HCO^+	+ C	1.00	~7.00x10^{-12}±50%	7705
CH_2^+	+ H_2	→ CH_3^+	+ H	1.00	1.16x 10^{-9} ±54%	b
CH_2^+	+ CH_4	→ $C_2H_4^+$	+ H_2	0.70	I.30x10'9 ±15%	b
		$C_2H_5^+$	+ 11	0.30		
CH_2^+	+ C_2H_2	→ $C_3H_3^+$	-1 H	1.00	2.5 OX1O-9 ±10%	8624
CH_2^+	+ N	→ CN^+	+ H_2		2.2 OX1O-1%5O%	8008
		HCN^+	+ H			
CH_2^+	+ N_2	→ No Reaction			<1.00x10^{-11}	c
		$\xrightarrow{M}$ Adduct			I.4ox1o-28 (M = Hc)	8632
CH_2^+	+ H_2O	→ CH_2OH^+	•t H	1.00	2. O5X1O-9 ±60%	b
CH_2^+	+ HCN	→ CH_2CN^+	+ }1	1.00	1.80x 10^{-9}±10%	8624
CH_2^+	+ HC_3N	→ $CHCCNH^+$	+ CH	1.00	4.10x10^{-9} ±30%	7911
c1 I_2^+	+ CO	→ No Reaction			<5. OOX1O-I2	7705
		$\xrightarrow{M}$ Adduct			2.00x10^{-27} (M = Hc)	8632
CH_3^+	-1 H	→ No Reaction			<1.00x10^{-11}	7901
CH_3^+	+ H_2	→ CH_5^+	+ hv	1.00	< 5 . 00x10^{-13}±30%	b
		$\xrightarrow{M}$ Adduct			1.10x10^{-28} (M = Hc)	8632
CH_3^+	+ HD	→ Products		1.00	8.10x 10^{-10}±20%	b
CH_3^+	+ D_2	→ Products		1.00	6.80x10^{-10}±20%	8202
c1 H_2D^+	+ H_2	$\xrightarrow{M}$ Adduct			4.8 OX1O-28 (M = Hc)	8632
c} HD_2^+	+ H_2	$\xrightarrow{M}$ Adduct			1.00x 10^{-28} (M = Hc)	8632

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reac					Br. Ratio	Rate Coefficient*	Reference
CD_3^+	+ H_2	→	Products		1.00	5.1 OX1O-10*1O%	b
		$\xrightarrow{M}$	Adduct			1.2o x1o-27 (M = He)	8632
CD_3^+	+ HD	→	Products		1.00	4.00×10^{-10} ±25%	8202
CH_3^+	+ CH_4	→	$C_2H_5^+$	+ H_2	1.00	1. IOX1O-9 ±15%	b
CH_3^+	+ C_2H_2	→	$C_3H_3^+$	+ H_2	1.00	1.15 X1 O-9 ±10%	b
CH_3^+	+ C_2H_4	→	$C_2H_3^+$	+ CH_4	0.46	1.06x 10-9 ±10%	b
			$C_3H_3^+$	+ H_2 + H_2	0.04		
			$C_3H_5^+$	+ H_2	0.51		
CH_3^+	+ C_2H_6	→	$C_2H_5^+$	+ CH_4	0.85	I.74X1O-9 ±10%	7712
			$C_3H_5^+$	+ H_2 + H_2	0.09		
			$C_3H_7^+$	+ H_2	0,06		
CH_3^+	+ C_4H_2	→	$C_3H_3^+$	+ C_2H_2	0.90	1.3 OX1O-9 *30%	8645
			$C_5H_3^+$	+ H_2	0.10		
CH_3^+	+ N	→	HCN^+	+ H_2		6.70×10^{-11} ±20%	b
			$HCNH^+$	+ 11			
CH_3^+	+ N_2	$\xrightarrow{M}$	Adduct			5.40×10^{-29} (M = He)	8632
CH_3^+	+ H_2O	→	No Reaction			$<1.00\times10^{-11}$	b
		$\xrightarrow{M}$	Adduct			6.00×10^{-25} (M= 11,0)	8632
CH_3^+	+ HCN	→	CH_3NCH^+	+ hv	1.00	2. OOX1O-10*1O%	b
		$\xrightarrow{M}$	CH_3NCH^+	+ M	1.00	1.07×10^{-23} (M= HCN)	b
CD_3^+	+ HCN	$\xrightarrow{M}$	CD_3NCH^+	+ M		2.20×10^{-23} (M= HCN)	8632
CH_3^+	+ CH_3CN	→	$C_2H_5^+$	+ HCN	0.37	1.8 OX1O-9 ±20%	8929
			$HCNH^+$	+ C_2H_4	0.58		
			$C_2H_5CNH^+$	+ hv	0.05		
		$\xrightarrow{M}$	$CH_3NCCH_3^+$	+ M	1.00	1.9x1o-22 ±20% (M= CH_3CN)	8929
CH_3^+	+ C_2H_3CN	→	CH_3NCH^+	+ C_2H_2	0.80	5.4 X1 O-9 *20%	9601
			$C_2H_5^+$	+ CH_3CN	0.10		
			$C_2H_3CNH^+$	+ C_2H_2	0.05		
			$C_3H_5^+$	+ HCN	0.05		
		$\xrightarrow{M}$	c-$C_3H_3^+$	+ HCN + H_2 + M	0.15	$\sim5.00\times10^{-24}$ (M = C_2H_3CN)	9601
			$C_3H_2N^+$	+ CH_4 + M	0.30		
			$C_4H_6N^+$	+ M	0.55		
CH_3^+	+ CH_3NC	→	CH_3CNH^+	+ CH_2	1.00	1.10×10^{-9} ±30%	8510
CH_3^+	+ HC_3N	→	$C_3H_3^+$	+ HCN	>0.95	1.5 X1 O-9 ±20%	9601
			$C_3H_6N^+$	+ hv	<0.05		
		$\xrightarrow{M}$	$C_3H_3^+$	+ HCN	0.40	-3.80×10^{-23} (M= HC_3N)	9601
			$C_3H_3N_2^+$		0.60		
CH_3^+	+ C_2N_2	→	CH_2CN^+	+ HCN	-0.80	4.4X1O-11 ±20%	9601
			$C_3H_6N^+$		~0.20		
		$\xrightarrow{M}$	Adduct			-8.00x10-24 (M= C_2N_2)	9601
CH_3^+	+ CO	→	No Reaction			$<1.00\times10^{-11}$	7701
		$\xrightarrow{M}$	Adduct			2.30×10^{-27} (M = He)	8632

Table 3 (cont.)
inn-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
CH_4^+	+ H	→	No Reaction		$<1.00 \times 10^{-11}$	7901
CH_4^+	+ H_2	→	CH_5^+ + 11	1.00	$3.50 \times 10^{-11} \pm 15\%$	b
CD_4^+	+ H_2	→	CHD_3^+ + HD		<1. OOX1O-12	7506
CH_4^+	+ CH_4	→	CH_5^+ + CH_3	1.00	1. I4X1O-9 ±15%	b
CD_4^+	+ CH_4	→	CH_4D^+ + CD_3	0.28	1.20 X10-9 ±20%	8913
			$CH_3D_2^+$ + CHD_2	0,36		
			$CH_2D_3^+$ + CH_2D	0.24		
			c1 ID_4^+ + CH3	0.12		
CH_4^+	+ C_2H_2	→	$C_2H_2^+$ + CH_4	0.53	2.72x1o.9 ±10%	b
			$C_2H_3^+$ + CH3	0.41		
			$C_3H_3^+$ + H_2 •t H	0.06		
CH_4^+	+ C2.314	→	$C_2H_4^+$ + CH_4	0.85	2.oox1o.9 ±30%	b
			$C_2H_5^+$ + CH_3	0.13		
			$C_3H_5^+$ + H_2 + H	0.03		
CH_4^+	+ C_2H_6	→	$C_2H_4^+$ + CH_4 + H_2	1.00	1.91 X1 O-9 *1O%	7712
CH_4^+	+ N_2	→	No Reaction		$<5.00 \times 10^{-13}$	7705
CH_4^+	+ H_2O	→	H_3O^+ + CH_3	1.00	$2.50 \times 10^{-9} \pm 10\%$	b
c1 I_4^+	+ HCN	→	$HCNH^+$ + CH3	0.98	3.3 OX1O-9±10%	b
			CH_3CNH^+ + H	0.02		
CH_4^+	+ HC_3N	→	$CHCCNH^+$ + CH_3	1.00	2.5 OX1O-9±30%	7911
CH_4^+	+ CO	→	HCO^+ + CH_3	0.96	1.08x 10-9 ±40%	b
			CH_3CO^+ + H	0.04		
CH_5^+	+ H	→	CH_4^+ + H_2	1.00	I.5OXIO-10*5O%	b
CD_5^+	+ H_2	→	No Reaction		<5.00X 10^{-13}	7506
CH_5^+	+ CH_4	→	No Reaction		<I. 00×10^{-12}	b
*CH_5^+	+ CH_4	→	Products	1.00	$3.00 \times 10^{-11} \pm 30\%$	b
		$\xrightarrow{M}$	Adduct		8.00x10-30 (M = He)	8632
CH_5^+	+ CD_4	→	Products	1.00	$2.90 \times 10^{-10} \pm 25\%$	8206
CH_5^+	+ C_2H_2	→	$C_2H_3^+$ + CH_4	1.00	1.48x 1o-9 ±20%	b
cl I_5^+	+ C_2H_4	→	$C_2H_5^+$ + CH_4	1.00	I.5OX1O-9 ±20%	7426
CH_5^+	+ C_2H_6	→	$C_2H_5^+$ + CH_4 + H_2	0.15	I.35X1O-9 ±15%	b
			$C_2H_7^+$ + CH_4	0.85		
CH_5^+	+ N	→	No Reaction		$<1.00 \times 10^{-11}$	b
CH_5^+	+ N_2	→	Nn Reaction		<1.oox1o-18	f
CH_5^+	+ H_2O	→	H_3O^+ + CH_4	1.00	3.70x 10^{-9} ±25%	7510
CH_5^+	+ HC_3N	→	$CHCCNH^+$ + CH_4	1.00	4.5 OX1O-9±30%	7911

Table 3 (cm!)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions					Br. Ratio	Rate Coefficient*	Reference
CH_5^+	+ CO	--->	HCO^+	+ CH_4	1.00	$9.90 \times 10^{-10} \pm 20\%$	8006
C_2H^+	+ H_2	--->	$C_2H_2^+$	+ 11	1.00	$1.24 \times 10^{-9} \pm 50\%$	b
C_2D^+	+ D_2	-->	$C_2D_2^+$	+ D	0.80	I.1OXIO-9 *20%	9021
			$C_2D_3^+$		0.20		
C_2H^+	+ CH_4	)	$C_2H_2^+$	+ c1 I_3	0.34	I.1OXIO-9 ±20%	7705
			$C_3H_3^+$	+ H_2	0.34		
			C31I_4^+	+ H	0.12		
			$C_3H_5^+$		0.20		
C_2H^+	+ C_2H_2		$C_4H_2^+$	+ H	1.00	$1.85 \times 10^{-9} \pm 30\%$	b
C_2H^+	+ C2,314	->	Products		1.00	I.7IX1O-9 *IO%	7012
C_2H^+	+ N	)	CH^+	+ CN	1.00	$9.50 \times 10^{-11} \pm 20\%$	b
C_2H^+	+ HCN	>	$C_2H_2^+$	+ CN	0.20	2.7 OX1O-9 ±10%	b
			$HCNH^+$	+ C_2	0.35		
			$CHCCN^+$	+ H	0.45		
C_2H^+	+ HC_3N	->	C411+	+ HCN	0.20	3.8 OX1O-9 ±25%	b
			$C_4H_2^+$	+ CN	0.12		
			$CHCCNH^+$	+ C_2	0.37		
			HC_5N^+	+ H	0.31		
$C_2H_2^+$	+ D	--->	C_2HD^+	+ H	1.00	$2.00 \times 10^{-10} \pm 20\%$	8916
$C_2H_2^+$	+ H_2	--->	$C_2H_3^+$	+ H	1.00	$1.00 \times 10^{-11} \pm 30\%$	b
		-M>	Adduct			1.30x1 o-27 (M = He)	8632
$C_2H_2^+$	+ HD	-->	C_2HD^+	+ H_2	1.00	$9.00 \times 10^{-11} \pm 20\%$	8713
$C_2H_2^+$	+ D_2	-->	$C_2H_2D^+$	+ D	-0.30	$1.40 \times 10^{-10} \pm 20\%$	8916
			C_2HD^+	+ HD	-0.70		
C_2HD^+	+ H_2	)	$C_2H_2^+$	+ HD	1.00	$2.00 \times 10^{-11} \pm 20\%$	8713
$C_2D_2^+$	+ D_2	)	$C_2D_3^+$	+ D	1.00	$4.00 \times 10^{-11} \pm 25\%$	9029
$C_2H_2^+$	+ CH_4	>	$C_3H_4^+$	+ H_2	0.21	$8.90 \times 10^{-10} \pm 10\%$	b
			$C_3H_5^+$	+ H	0.79		
$C_2H_2^+$	+ CD_4	>	$C_3H_2D_2^+$	+ D_2	0.07		8931
			$C_3HD_3^+$	+ HD	0.12		
			$C_3H_2D_3^+$	+ D	0.40		
			$C_3HD_4^+$	+ }1	0.41		
			Adduct		0.02		
$C_2H_2^+$	+ C_2H_2	>	$C_4H_2^+$	+ H_2	0.32	$1.40 \times 10^{-9} \pm 15\%$	b
			$C_4H_3^+$	+ 11	0.68		
		_M,	Adduct			1.60×10^{-26} ($M = CO_2$)	8632
$C_2H_2^+$	+ C2,314	--->	$C_2H_4^+$	+ C_2H_2	0.30	1.38x 1o-9 ±15%	b
			$C_3H_3^+$	+ CH_3	0.48		
			$C_4H_5^+$	+ H	0.23		

Table 3 (cent)
Inn-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient	Reference
$C_2H_2^+$	+ C_2H_6	→	$C_2H_4^+$ + C2114	0.18	1.38×10^{-9} ±10%	b
			$C_2H_5^+$ + C_2H_3	0.09		
			$C_3H_3^+$ + CH_3 + H_2	0.06		
			$C_3H_4^+$ + CH_4	0.01		
			$C_3H_5^+$ + CH_3	0.54		
			$C_4H_5^+$ + H_2 + 11	0.05		
			$C_4H_7^+$ + H	0.09		
$C_2H_2^+$	+ C_4H_2	→	$C_4H_2^+$ + C_2H_2	0.90	1.40×10^{-9} ±30%	8645
			$C_6H_3^+$ + H	0.10		
$C_2H_2^+$	+ N	→	CH^+ + HCN	0.05	2.50×10^{-10} ±20%	e, b
			C_2N^+ + H_2	0.35		
			$CHCN^+$ + }1	0.60		
$C_2H_2^+$	+ N_2	→	No Reaction		<2.0x10-11	d
$C_2H_2^+$	+ H_2O	→	H_3O^+ + C_2H	1.00	2.2 OX IO-10±10%	7714
$C_2H_2^+$	+ HCN	→	$HCNH^+$ + C_2H	0.66	3.90×10^{-10} ±25%	8002
			$CHCCNH^+$ + H	0.34		
		M,	Adduct		3.60×10^{-9} (in 0.44 Torr of He)	9026
$C_2H_2^+$	+ CH3CN	→	CH_3CNH^+ + C_2H	0.22	3.8 OX1O-9±25%	9026
			$C_3H_4^+$ + HCN	0.28		
			$C_3H_5^+$ + CN	0.28		
			Adduct	0.23		
$C_2H_2^+$	+ HC_3N	→	$C_4H_2^+$ + HCN	0.45	3.45 X1 O-9 i20%	b
			$H_3C_5N^+$	0.55		
$C_2H_2^+$	+ C_2N_2	→	No Reaction		<1. 0x10-11	9501
$C_2H_3^+$	+ 11	→	$C_2H_2^+$ + H_2	1.00	6.8 OX1O-11*2O%	9603, b
$C_2H_3^+$	+ H_2	→	No Reaction		<1.00 x 10-12	b
		M,	Adduct		2.00 x 1o-29 (M = He)	8632
$C_2H_3^+$	+ CH_4	→	$C_3H_5^+$ + H_2	1.00	1.90×10^{-10} ±20%	b
*$C_2H_3^+$	+ C_2H_2	→	$C_2H_3^+$ + ● C2J12	-0.70	7.20×10^{-10} ±10%	8624
			$C_4H_3^+$ + H_2	-0.30		
$C_2H_3^+$	+ C_2H_2	→	$C_4H_3^+$ + H_2	1.00	2.40×10^{-10} ±30%	b
		M,	Adduct		2.98x 1O-25 (M = 11_2)	8632
$C_2H_3^+$	+ C2,314	→	$C_2H_5^+$ + C_2H_2	1,00	8.20×10^{-10} ±10%	b
$C_2H_3^+$	+ C_2H_6	→	$C_2H_5^+$ + C2114	0.47	6.20×10^{-10} ±10%	b
			$C_3H_5^+$ + CH_4	0.40		
			$C_4H_7^+$ + H_2	0.13		
$C_2H_3^+$	+ N	→	C}ICN$^+$ + H_2	1.00	2.40×10^{-11}	e, 8613
$C_2H_3^+$	+ N_2	→	No Reaction		<1. OOX1O-2O	f
$C_2H_3^+$	+ H_2O	→	H_3O^+ + C_2H_2	1.00	1.11XI O-9 ±10%	7714
$C_2H_3^+$	+ HCN	→	$HCNH^+$ + C_2H_2	1.00	2.3 OX1O-9±40%	b
$C_2H_3^+$	+ HC_3N	→	$CHCCNH^+$ + C_2H_2	1,00	3.8 OX1O-9±20%	b

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
$C_2H_3^+$	+ C_2N_2	→	$HC_2N_2^+$ + C_2H_2	1.00	$5.50 \times 10^{-10} \pm 40\%$	b
		$\xrightarrow{M}$	Adduct		1.40×10^{-10} (in 0.33 Torr of He)	8412
$C_2H_4^+$	+ 11	→	$C_2H_3^+$ + H_2	1.00	$3.00 \times 10^{-10} \pm 20\%$	b
$C_2H_4^+$	+ H_2	→	No Reaction		<4.00%1014	b
		$\xrightarrow{M}$	No Reaction		<1. OOX1O-3O (M = He)	8632
$C_2H_4^+$	+ CH_4	→	No Reaction		$<1.00 \times 10^{-13}$	b
$C_2H_4^+$	+ C2112	→	$C_3H_3^+$ + CH_3	0.77	$8.40 \times 10^{-10} \pm 10\%$	b
			$C_4H_5^+$ + H	0.23		
$C_2H_4^+$	+ C2314	→	$C_3H_5^+$ + CH_3	0.91	$8.30 \times 10^{-10} \pm 10\%$	b
			$C_4H_7^+$ + }1	0.09		
		$\xrightarrow{M}$	Adduct		6.30×10^{-26} (M= CO,)	8632
$C_2H_4^+$	+ C_2H_6	→	$C_3H_6^+$ + CH_4	0.07	$5.15 \times 10^{-12} \pm 10\%$	b
			$C_3H_7^+$ + CH_3	0.93		
$C_2H_4^+$	+ N_2	→	No Reaction		$<1.00 \times 10^{-11}$	c
$C_2H_4^+$	+ H_2O	→	No Reaction		$<1.00 \times 10^{-12}$	7714
$C_2H_4^+$	+ HCN	→	No Reaction		$<2.00 \times 10^{-11}$	b
		$\xrightarrow{M}$	Adduct		8.70×10^{-11} (in 0.45 Torr of He)	8011
$C_2H_4^+$	+ HC_3N	→	$H_2C_3N^+$ + C_2H_3	0.85	1.4 X1 O-9 ±20%	d, 7911
			$H_4C_5N^+$ + H	0.15		
$C_2H_4^+$	+ C_2N_2	)	No Reaction		$<1.0 \times 10^{-11}$	9501
$C_2H_5^+$	+ H	→	$C_2H_4^+$ + H_2	1.00	-I. OOX1O-11*3O%	b
$C_2H_5^+$	+ H_2	→	No Reaction		<4.00%10-14	b
		$\xrightarrow{M}$	No Reaction		<I. OOX1O-3O (M = He)	8632
$C_2H_5^+$	+ CH_4	→	$C_3H_7^+$ + H_2	1.00	9. OOX1O-14*15%	b
		$\xrightarrow{M}$	Adduct		I.4OX1O-3O (M= CH_4)	b
C2115+	+ C_2H_2	→	$C_2H_5^+$ + C_2H_2	0.79	$9.00 \times 10^{-10} \pm 20\%$	b
			$C_3H_3^+$ + CH_4	0.08		
			$C_4H_5^+$ + H_2	0.13		
		$\xrightarrow{M}$	Adduct		I.34x1o-25 (M = He)	8632
$C_2H_5^+$	+ C_2H_4	→	$C_3H_5^+$ + CH_4	1.00	$3.55 \times 10^{-10} \pm 15\%$	b
		$\xrightarrow{M}$	Adduct			b
$C_2H_5^+$	+ C_2H_6	→	$C_3H_7^+$ + CH_4	0.14	$3.90 \times 10^{-11} \pm 0\%$	b
			$C_4H_9^+$ + H_2	0.86		
$C_2H_5^+$	+ C_3H_8	→	i-$C_3H_7^+$ + C_2H_6	1.00	$6.30 \times 10^{-10} \pm 5\%$	7630
$C_2H_5^+$	+ N	→	No Reaction		$<1.40 \times 10^{-11}$	e
$C_2H_5^+$	+ N_2	→	No Reaction		$<1.0 \times 10^{-11}$	d

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
$C_2H_5^+$	+ H_2O	→	H_3O^+ + C_2H_4	1.00	1.86x10-9 ±65%	b
$C_2H_5^+$	•t HCN	-)	$HCNH^+$ + C_2H_4	1.00	2.70x1O-9 ±20%	8011
$C_2H_5^+$	+ CH_3CN	→	CH_3CNH^+ + C_2H_4	1.00	3.80x 10^{-9} *20%	8929
$C_2H_5^+$	+ C_2N_2	→	H $C_2N_2^+$ + C2114	1.00	8.00x 10^{-11}±50%	b
		-M→	Adduct		1.2 OX1O-10 (in 0.30 Torr of He)	b
$C_2H_5^+$	+ HC_3N	- →	$CHCCNH^+$ + C_2H_4	1.00	3.55 x10^{-9}±20%	b
$C_2H_6^+$	-1 11	- .	$C_2H_5^+$ + H_2	1.00	1.00x10^{-10}±20%	b
$C_2H_6^+$	+ H_2	→	No Reaction		<I. 00x10^{-11}	7701
$C_2H_6^+$	+ CH_4	- →	No Reaction		<I. 00x10^{-12}	7712
$C_2H_6^+$	+ C_2H_2	→	$C_2H_5^+$ + C_2H_3	0.19	1.3 OX1O-9 ±10%	b
			$C_3H_5^+$ + c113	0.70		
			$C_4H_7^+$ + H	0.11		
$C_2H_6^+$	+ C_2H_4	→	$C_2H_4^+$ + C_2H_6	1.00	1. I5X1O-9 ±10%	7712
$C_2H_6^+$	+ C_2H_6	)	$C_3H_8^+$ + CH_4	0.42	1.90x10^{-11}±10%	b
			$C_3H_9^+$ + CH_3	0.58		
$C_2H_6^+$	+ H_2O	→	H_3O^+ t C_2H_5	1.00	2.95x 10^{-9}±10%	7701
$C_2H_6^+$	+ HCN	)	$HCNH^+$ + C_2H_5	0.95	1.2x1 o-9 ±10%	d
			$H_6C_3N^+$ + H	0.05		
C_3H^+	+ H_2	- →	c-$C_3H_2^+$ + H	-0.04	2.60x10^{-11}±30%	b
			l-$C_3H_2^+$ + H	-0.16		
			c-$C_3H_3^+$	-0.52		
			l-$C_3H_3^+$	-0.28		
		-M→	Adduct		2.30x 10^{-27} (M = He)	8632
C_3H^+	+ CH_4	- →	$C_2H_3^+$ + C_2H_2	0.70	5.50x10^{-10}±30%	8304
			$C_3H_3^+$ + c112	0.20		
			$C_4H_3^+$ + H_2	0.10		
C_3H^+	+ C_2H_2	- .	$C_5H_2^+$ + H	1.00	8.40x10^{-10}±50%	b
C_3H^+	+ C_2I 14	- →	$C_3H_3^+$ + C_2H_2	0.95	9.5 OX1O-W3O%	8304
			$C_5H_3^+$ + H_2	0.05		
C_3H^+	+ CH_2CCH_2	-)	$C_4H_3^+$ + C_2H_2	1.00	1.40 x10^{-9}±20%	8429
C_3H^+	+ CH_3CCH	- →	$C_4H_3^+$ + C_2H_2	1.00	1.40 x10^{-9} *20%	8429
C_3H^+	+ C_4H_2	-- →	$C_5H_2^+$ + C_2I I	0.85	1.20 X10-9 ±30%	8645
			C_5H^+ + C_2H_2	0.10		
			$C_4H_2^+$ + C_3I I	0.05		
C_3H^+	+ NH_3	-- ,	NH_3^+ + C3H	0,20	1.65x 10^{-9} ±30%	b
			NH_4^+ + C3	0.45		
			$HCNH^+$ + C_2H_2	0.25		
			CH_2CHCN^+ + H	0.10		
C_3H^+	+ N_2	- →	No Reaction		<1.00x10^{-13}	8304

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions			Br. Ratio	Rate Coefficient[a]	Reference
C_3H^+ + H_2O →	$C_2H_3^+$	+ CO	0.40	$4.50 \times 10^{-10} \pm 30\%$	8304
	HCO^+	+ C_2H_2	0.55		
	$CHCCO^+$	+ H_2	0.05		
C_3H^+ •t HCN →	$HCNH^+$	-1 C3	0.09	$4.00 \times 10^{-11} \pm 30\%$	b
	$H_2C_4N^+$	+ hv	0.91		
$\xrightarrow{M}$	Adduct			1. OOX1O-9 (in 0.35 Torr 01 he)	8311
C_3H^+ + CH_3CN →	$C_2H_3^+$	+ HC_3N	0.20	$3.00 \times 10^{-9} \pm 30\%$	b
	CH_3CNH^+	+ C_3	0.15		
	$CHCCNH^+$	+ C_2H_2	0,33		
	$H_4C_5N^+$		0.30		
C_3H^+ + C_2N_2 →	$HC_5N_2^+$		**1.00**	>4.4OX1O-10*3O%	8304
C_3H^+ + HC_3N →	$H_2C_6N^+$		1.00	1.25x 1O-9 ±20%	b
C_3H^+ + CO $\xrightarrow{M}$	Adduct			2.90x o-27 (M = He)	8632
l-C_3H^+ + D →	l-C_3D^+	+ H	1.00	$5.00 \times 10^{-10} \pm 20\%$	8916
l-C_3H^+ + H_2 →	c-$C_3H_2^+$	+ H	1.00	$6.00 \times 10^{-12} \pm 30\%$	8916
l-C_3H^+ + D_2 →	c-C_3HD^+	+ D	0.50	$6.00 \times 10^{-12} \pm 30\%$	8916
	c-$C_3D_2^+$	+ H	0.50		
C_3D^+ + D_2 →	$C_3D_2^+$	+ D	1.00	$2.70 \times 10^{-11} \pm 20\%$	8726
$C_3H_2^+$ + H_2 →	No Reaction			$<5.00 \times 10^{-14}$	b
$\xrightarrow{M}$	No Reaction			<1.00x1O-30 (M = He)	8632
$C_3H_2^+$ + C_2H_2 →	$C_5H_3^+$	+ H	1.00	$8.50 \times 10^{-10} \pm 25\%$	8805, 8712 8624, 7105
$C_3H_2^+$ + CH_2CCH_2 →	$C_4H_2^+$	-t C_2H_4	0.04	$1.40 \times 10^{-9} \pm 20\%$	8429
	$C_4H_3^+$	+ C_2H_3	0.14		
	$C_4H_4^+$	-t C_2H_2	0.50		
	$C_5H_3^+$	+ CH3	0.09		
	$C_6H_5^+$	+ H	0.21		
$C_3H_2^+$ + CH_3CCH →	$C_4H_2^+$	+ C_2H_4	0.09	$1.30 \times 10^{-9} \pm 20\%$	8429
	$C_4H_3^+$	+ C_2H_3	0.12		
	$C_4H_4^+$	+ C_2H_2	0.41		
	$C_5H_3^+$	+ CH3	0.18		
	$C_6H_5^+$	+ H	0.20		
$C_3H_2^+$ + HCN →	Products		1.00	$1.60 \times 10^{-10} \pm 10\%$	8624
c-$C_3H_2^+$ + H →	No Reaction			$<7.00 \times 10^{-12}$	8916
c-$C_3H_2^+$ + D →	c-C_3HD^+	+ H	1.00	1. OOXIO-10*2O%	8916

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
$c\text{-}C_3H_2^+$	+ D_2	→ No Reaction			<I. 00X10-12	8916
$c\text{-}C_3H_2^+$	+ C_2H_2	→ $C_5H_3^+$	+ H	1.00	$9.00 \times 10^{-10} \pm 20\%$	8712
$l\text{-}C_3H_2^+$	+ H	→ $l\text{-}C_3H^+$	+ H_2	1.00	$6.00 \times 10^{-11} \pm 20\%$	8916
$l\text{-}C_3H_2^+$	+ D	→ $c\text{-}C_3HD^+$	+ H	0.50	1. OOX1O-9 ±20%	8916
		$l\text{-}C_3HD^+$	+ H	0.50		
$l\text{-}C_3H_2^+$	+ D_2	→ No Reaction			$<1.00 \times 10^{-12}$	8916
$l\text{-}C_3H_2^+$	+ C_2H_2	→ $C_5H_3^+$	+ }[	1.00	1.10×10^{-9} *20%	b
$C_3H_3^+$	+ H_2	→ No Reaction			$<1.00 \times 10^{-13}$	8309
		$\xrightarrow{M}$ No Reaction			<1.00x1O-30 (M = He)	8632
$C_3H_3^+$	+ C_2H_2	→ No Reaction			$<1.00 \times 10^{-11}$	8624
$C_3H_3^+$	+ CH_2CCH_2	→ No Reaction			$<1.00 \times 10^{-11}$	8429, 8440
$C_3H_3^+$	+ CH_3CCH	→ No Reaction			$<1.00 \times 10^{-11}$	8429, 8440
$C_3H_3^+$	+ C_4H_2	→ No Reaction			<1. OOX1O-I3	8645
		$\xrightarrow{M}$ Adduct			-1. OOX1O-9 (in 0.32 Torr of He)	8645
$C_3H_3^+$	+ N	→ $CHCCNH^+$	+ H	1.00	$1.30 \times 10^{-10} \pm 20\%$	8613
$C_3H_3^+$	+ N	→ $CHCCN^+$	+ H2	1.00	2.30×10^{-11}	e
$C_3H_3^+$	+ HCN	→ No Reaction			$<2.00 \times 10^{-11}$	8624
$c\text{-}C_3H_3^+$	+ H	→ No Reaction			<4. OOX1O-11	9602
$c\text{-}C_3H_3^+$	+ H_2	$\xrightarrow{M}$ No Reaction			$\leq 5.00 \times 10^{-28}$ (M = He)	9401
$c\text{-}C_3H_3^+$	+ CH_4	→ No Reaction			$<2.00 \times 10^{-11}$	9401
$c\text{-}C_3H_3^+$	+ C_2H_2	→ No Reaction			<8. OOX1O-13	9401, b
		$\xrightarrow{M}$ No Reaction			<5.oox1o-28 (M = He)	9401
$c\text{-}C_3H_3^+$	+ C_2H_4	→ No Reaction			$<1.00 \times 10^{-11}$	9401, 8209
$c\text{-}C_3H_3^+$	+ C_2H_6	→ No Reaction			$<2.00 \times 10^{-11}$	9401
$c\text{-}C_3H_3^+$	+ NH_3	→ No Reaction			$<2.00 \times 10^{-11}$	9401
		$\xrightarrow{M}$ No Reaction			s5.oox1o-28 (M = He)	9401
C-C3}13+	+ N2	→ No Reaction			$<2.00 \times 10^{-11}$	9401

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions					Br. Ratio	Rate Coefficient*	Reference
c-$C_3H_3^+$	+ H_2O	$\xrightarrow{M}$	No Reaction			s5.00x1 o-28 (M = he)	9401
C-$C_3H_3^+$	+ O_2	→	No Reaction			<2.00X 10^{-11}	9401
c-$C_3H_3^+$	+ HCN	→	No Reaction			<2.00x10^{-11}	8624
		$\xrightarrow{M}$	No Reaction			≤5.00X10^{-28} (M = He)	9401
c-$C_3H_3^+$	+ CH_3CN	→	No Reaction			<2.00X 10^{-11}	9401
		$\xrightarrow{M}$	Adduct			7.00X10^{-10} (in 0.30 Torr of He)	9401
c-$C_3H_3^+$	+ HC_3N	→	No Reaction			<2. OOX1O-11	9401
C-$C_3H_3^+$	+ CO	→	No Reaction			<2.00x10^{-11}	9401
c-$C_3H_3^+$	+ CH_3OH	→	No Reaction			<2.00X 10^{-11}	9401
		$\xrightarrow{M}$	No Reaction			≤5.00X10^{-28} (M = He)	9401
l-$C_3H_3^+$	+ H	→	No Reaction			C4.OOX1O-11	9602
l-$C_3H_3^+$	+ H_2	$\xrightarrow{M}$	No Reaction			≤5.00X10^{-28} (M = He)	9401
1-$C_3H_3^+$	+ C_2H_2	→	c-$C_3H_3^+$	+ C_2H_2	1.00	2.10x IO-10*42%	9401, b
		$\xrightarrow{M}$	Adduct		1.00	-2.5ox1o-24 (M= C_2H_2)	9401
l-$C_3H_3^+$	+ C_2H_4	→	$C_5H_5^+$	+ H_2		1.1 OX1O-9 ±50%	8209
			$C_5H_7^+$				
l-$C_3H_3^+$	+ C_4H_2	→	c-$C_3H_3^+$	+ C_4H_2	0.24	1.4 OX1O-9 ±50%	b
			$C_5H_3^+$	+ C_2H_2	0.76		
l-$C_3H_3^+$	+ NH_3	→	NH_4^+	+ C_3H_3	0.60	3.00x10^{-10}±20%	9401
			$HCNH^+$	+ C_2H_4	0.40		
		$\xrightarrow{M}$	Adduct		1.00	<s. oo,1 o-24 (M= NH_3)	9401
l-$C_3H_3^+$	+ H_2O	$\xrightarrow{M}$	Adduct		1.00	8.00x10^{-12} (in 0.3 Torr of He)	9401
l-$C_3H_3^+$	+ HCN	$\xrightarrow{M}$	Adduct		1.00	4.80x10^{-10} (in 0.3 Torr of He)	9401
l-$C_3H_3^+$	+ CH_3CN	→	Products		1.00	1.60x10^{-10}±20%	9401
		$\xrightarrow{M}$	Adduct		1.00	3.3 OX1O-9 (in 0.3 Torr of He)	9401
l-$C_3H_3^+$	+ HC_3N	→	Products		1.00	9. OX1O-10	9401
l-$C_3H_3^+$	+ CH_3OH	→	CH_3O^+	+ C_3H_4	1.00	3.4x10^{-10}	9401
		$\xrightarrow{M}$	Adduct		1.00	<5.00x10^{-24} (M= CH_3OH)	9401
$C_3H_4^+$	+ H_2	→	No Reaction			<I.00x10^{-13}	8309
		$\xrightarrow{M}$	No Reaction			<I.00x10^{-30} (M = He)	8632
$C_3H_4^+$	+ C_2H_2	→	$C_5H_5^+$	+ H	1.00	4.9 OX1O-I%1O9%	8624

Table 3 (cont)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

					Ratio	Coefficient	ference
$C_3H_4^+$	+ HCN		No Reaction			$<1.00\times10^{-11}$	8624
$CH_2CCH_2^+$	+ H	→	$C_3H_3^+$	+ H_2	1.00	1.7 OX1O-11	9602
$CH_2CCH_2^+$	+ CH_2CCH_2		$C_4H_4^+$	+ C2114	0.05	1.1 OX1O-9 ±20%	b
			$C_4H_6^+$	+ C_2H_2	0.01		
			$C_5H_5^+$	+ CH_3	0.01		
			$C_6H_5^+$	+ H_2 + }1	0.07		
			c-$C_6H_7^+$	+ H	0.61		
			ac-$C_6H_7^+$	+ 11	0.26		
CH_3CCH^+	+ H	→	$C_3H_3^+$	+ H_2	1.00	3.00×10^{-11}	9602
CH_3CCH^+	+ CH_3CCH	→	$C_3H_5^+$	+ C3H3	0.18	I.1OXIO-9 ±20%	b
			C41I_4^+	+ C_2H_4	0.02		
			$C_4H_6^+$	+ C_2H_2	0.02		
			$C_5H_5^+$	+ CH3	0.02		
			$C_6H_5^+$	+ H_2 + H	0.08		
			c-$C_6H_7^+$	+ H	0.30		
			ac-$C_6H_7^+$	+ 11	0.38		
$C_3H_5^+$	+ H		$C_2H_2^+$	+ CH_4	0.05	1.00×10^{-11}	9602
			$C_2H_3^+$	+ CI13	0.95		
$C_3H_5^+$	+ H_2	→	No Reaction			<2. OOX1O-11	d
		$\xrightarrow{M}$	No Reaction			<1. OOX1O-3O (M = He)	8632
$C_3H_5^+$	+ c114	→	No Reaction			<3.5 OX1O-11	d
$C_3H_5^+$	+ C_2H_2	→	$C_5H_5^+$	+ H_2	1.00	3.80×10^{-10} ±10%	d
$C_3D_5^+$	+ C_2D_2	→	$C_5D_5^+$	+ D_2	1.00	2.70×10^{-10} ±10%	d
$C_3H_5^+$	+ C2,314	→	$C_5H_7^+$	+ H_2	0.70	1.70×10^{-10} ±10%	d
			$C_5H_9^+$		0.30		
		$\xrightarrow{M}$	Adduct			5.40x 10^{-26} (M = H_2)	8632
$C_3H_5^+$	+ C_2H_6	→	No Reaction			$<5.00\times10^{-11}$	d
$C_3H_5^+$	+ C_3H_6	$\xrightarrow{M}$	Adduct			6.4 OX1O-26 (M = CO_2)	8632
$C_3H_5^+$	+ N	→	$C_2H_4^+$	+ HCN	0.88	1.25×10^{-10} ±20%	8613
			c1 I_2CHCN$^+$	+ H_2	0.12		
$C_3H_5^+$	+ N_2	→	No Reaction			<1. OOX1O-2O	f
$C_3H_5^+$	+ HCN	→	Adduct	+ hv		~5.00×10^{-11}	d
		$\xrightarrow{M}$	Adduct				
$C_3H_5^+$	+ C_2H_3CN	→	$C_2H_3CNH^+$	+ C3114	1.00		d
		$\xrightarrow{M}$	Adduct				
$C_3H_5^+$	+ HC_3N	→	$H_2C_3N^+$	+ C3114	1.00	~1.00×10^{-10}	d
		$\xrightarrow{M}$	Adduct			$<1.00\times10^{-23}$	d
$C_3H_5^+$	+ C_2N_2	→	No Reaction			$<1.00\times10^{-11}$	9501

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
$C_3H_6^+$	+ C_3H_6	)	$C_3H_7^+$ + C_3H_5	0.15	$1.40 \times 10^{-9} \pm 10\%$	d
			$C_4H_7^+$ + C_2H_5	0.20		
			$C_4H_8^+$ + C_2H_4	0.35		
			$C_5H_9^+$ + CH_3	0.30		
$C_3H_6^+$	+ HCN	-)	Products		$3.00 \times 10^{-10} \pm 10\%$	d
c-$C_3H_6^+$	+ HCN	- ›	CH_2CNH^+ + C_2H_4	0.40	$4.00 \times 10^{-10} \pm 10\%$	d
			$H_6C_4N^+$ + H	0.60		
$C_3H_7^+$	+ 11	)	$C_3H_6^+$ + H_2	1.00	3.7 OX1O-11	9603
$C_3H_7^+$	+ H_2	›	No Reaction			8632
$C_3H_7^+$	+ N	›	No Reaction		$<1.00 \times 10^{-11} \pm 20\%$	8613
$C_3H_7^+$	+ H_2O	›	No Reaction		<1.oox1o-I6	f
$C_4H_2^+$	+ H_2	– +	No Reaction		$<1.00 \times 10^{-13} \pm 30\%$	8645
$C_4H_2^+$	•1 C_2H_2	- ,	$C_6H_3^+$ + 11	0.05	$2.80 \times 10^{-10} \pm 65\%$	b
			$C_6H_4^+$ + hv	0.95		
		-M›	Adduct		2.3ox1o-26 (M = CO_2)	8632
$C_4H_2^+$	+ C_2D_2	- →	C_4HD^+ + C_2HD	0.52	$5.90 \times 10^{-10} \pm 20\%$	9033
			Adduct + hv	0.48		
$C_4H_2^+$	+ CH_3CCH	-)	$C_5H_4^+$ + C_2H_2	0.10		8429
			$C_7H_5^+$ + 11	0.90		
$C_4H_2^+$	+ C_4H_2	– ›	$C_6H_2^+$ + C_2H_2	0.83	1.4 OX1O-9 ±20%	8429
			$C_8H_2^+$ + H_2	0.17		
			$C_8H_3^+$ + 11	0.01		
		_M,	Adduct		I.2ox1o.9 (in 0.32 Torr of He)	8645
$C_4H_2^+$	+ C_4H_4	-)	$C_4H_4^+$ + C_4H_2	0.13	I.4OX1O.9 ±20%	8429
			$C_6H_4^+$ + C_2H_2	0.80		
			$C_8H_4^+$ + H_2	0.06		
			$C_8H_6^+$ + hv	<0.01		
$C_4H_2^+$	+ HCN	- ›	No Reaction		$<2.00 \times 10^{-11}$	8624
$C_4H_2^+$	+ HC_3N	- ›	$H_3C_7N^+$	1.00	$1.70 \times 10^{-9} \pm 20\%$	8518
$C_4H_2^+$	+ C_2N_2	- ›	Products	1.00	$2.00 \times 10^{-10} \pm 10\%$	9501
$C_4H_2^+$	+ CO	-M›	Adduct	1.00	$2.30 \times 10^{-27} \pm 20\%$ (M = He)	8914

Table 3 (rent)
Ion-Molecule Reactions Relavent LO Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
$C_4H_3^+$	+ C_2H_2	→	$C_6H_5^+$ + hv	1.00	$2.20\times10^{-10}\pm10\%$	b
		$-^M$,	Adduct		1.50×10^{-26} (M= CO_2)	8632
$C_4H_3^+$	+ C_2D_2	→	$C_4H_2D^+$ + C_2HD	0.30	$3.00\times10^{-10}\pm20\%$	9033
			Adduct + hv	0.70		
$C_4H_3^+$	+ CH_3CCH	→	$C_5H_5^+$ + C_2H_2	>0.96		8429
			$C_6H_5^+$ + CH_2	<0.04		
$C_4H_3^+$	+ C_4H_2	→	$C_6H_3^+$ + C_2H_2	1.00	$7.40\times10^{-10}\pm20\%$	8429
		$-^M$→	Adduct		-9. OOXIO-1O (in 0.32 Torr of He)	8645
$C_4H_3^+$	+ C_4H_4	→	$C_4H_5^+$ + C_4H_2	0.25	I. IOX1O-9 ±20%	8429
			$C_6H_5^+$ + C_2H_2	0.65		
			$C_8H_6^+$ + H	0.10		
$C_4H_3^+$	+ c-C_6H_6	→	$C_6H_7^+$ + C_4H_2	1.00		8702
$C_4H_3^+$	+ N2	→	No Reaction		<I. OOX1O-2O	f
$C_4H_3^+$	+ H_2O	→	No Reaction		<1.oox1o-16	f
$C_4H_3^+$	+ HCN	→	No Reaction		<5. OOX1O-11	8624
$C_4H_3^+$	+ C_2N_2	→	Products	1.00	$1.90\times10^{-10}\pm10\%$	9501
$C_4H_3^+$	+ CO	→	Adduct	1.00	$\sim1.00\times10^{-28}\pm20\%$ (M = He)	8914
$C_4H_5^+$	+ CH_3CCH	→	$C_6H_5^+$ + CH_4	0.40		8429
			$C_7H_7^+$ + H_2	0.60		
$C_4H_5^+$	+ C_4H_2	→	$C_6H_5^+$ + C_2H_2	1.00		8429
$C_4H_5^+$	+ C_4H_4	→	$C_6H_7^+$ + C_2H_2	1.00		8429
$C_4H_7^+$	+ N	→	No Reaction		$<1.00\times10^{-11}\pm20\%$	8613
$C_5H_5^+$	+ C_2H_2	→	$C_7H_7^+$ + hv	1.00	$3.1\ OX\ 10^{-11}\pm40\%$	8708
$C_5H_5^+$	+ CH_3CCH	→	$C_6H_7^+$ + C_2H_2	0.56		8429
			$C_8H_7^+$ + H_2	0.44		
$C_5H_5^+$	+ C_4H_2	→	$C_7H_5^+$ + C_2H_2		$2.20\times10^{-10}\pm40\%$	8708
			$C_7H_7^+$ + C_2			
			$C_9H_7^+$ + hv			
$C_6H_4^+$	+ H	→	$C_6H_5^+$	1.00	$3.3\ 0\times10^{-11}$	9602, 9201
$C_6H_5^+$	+ C_2H_2	→	$C_8H_7^+$	>0.98	$4.00\times10^{-10}\pm20\%$	8709
			$C_8H_6^+$ + H	<0.02		

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions			Br. Ratio	Rate Coefficient*	Reference
$C_6H_5^+$ + C_4H_2 →	$C_8H_5^+$	+ C_2H_2	1.00		8429
$C_6H_5^+$ + C_4H_4 →	$C_8H_7^+$	+ C_2H_2	1.00		8429
ac-$C_6H_5^+$ + H →	No Reaction			$<5.00 \times 10^{-12}$	9201
ac-$C_6H_5^+$ + H_2 →	$C_6H_7^+$	+ hv	1.00	$5.00 \times 10^{-11} \pm 20\%$	9201, b
ac-$C_6H_5^+$ + CO →	Adduct		1.00	$2.00 \times 10^{-10} \pm 20\%$	8914
c-$C_6H_5^+$ + }1 →	No Reaction			$<1.00 \times 10^{-11}$	9602, 9201
c-$C_6H_5^+$ + H_2 →	No Reaction			<5. OOX1O-13	b
c-$C_6H_5^+$ + CH_4 →	$C_7H_7^+$	+ H_2	1.00	$7.50 \times 10^{-11} \pm 30\%$	8920
c-$C_6H_5^+$ + C_2H_2 →	$C_8H_6^+$	+ 11	0.60	$1.30 \times 10^{-10} \pm 30\%$	8920
	$C_8H_7^+$	+ hv	0.40		
c-$C_6H_5^+$ + C_2H_4 →	$C_6H_7^+$	+ C_2H_2	0.50	$1.70 \times 10^{-10} \pm 30\%$	8920
	$C_8H_7^+$	+ H_2	0.50		
c-$C_6H_5^+$ + C_2H_6 →	$C_6H_7^+$	+ C_2H_4	0.97	1.3 OX1O-1%3O5-G	8920
	$C_7H_7^+$	+ CH_4	0.03		
c-Cd I_5^+ + CH_2CCH_2 →	$C_7H_7^+$	+ C_2H_2	0.30	5.2 OX1O-1%3O%	8920
	$C_9H_7^+$	+ H_2	0.70		
c-$C_6H_5^+$ + CH_3CCH →	$C_7H_7^+$	+ C_2H_2	0.18	$2.30 \times 10^{-10} \pm 30\%$	b
	$C_9H_7^+$	+ H_2	0.78		
	$C_9H_8^+$	+ H	0.05		
c-$C_6H_5^+$ + CH_3CHCH_2 →	$C_7H_7^+$	+ C_2H_4	1.00	$3.40 \times 10^{-10} \pm 30\%$	8920
c-$C_6H_5^+$ + C_4H_6 →	$C_7H_7^+$	+ C3114	0.35	$3.30 \times 10^{-10} \pm 30\%$	8920
	$C_9H_7^+$	+ CH_4	0.10		
	$C_9H_8^+$	+ CH_3	0.20		
	$C_{10}H_8^+$	+ H_2 + H	0.20		
	$C_{10}H_9^+$	+ H_2	0.10		
c-$C_6H_5^+$ + CO →	No Reaction			<5. OOX1O-13	8914
c-$C_6H_6^+$ + H →	$C_6H_7^+$		>0.70	2.1 OX1O"1O	9602, 9201
	$C_6H_5^+$	+ Hz	<0.30		
c-$C_6H_6^+$ + H_2 →	No Reaction			$<I.00 \times 10^{-12}$	9201
c-$C_6H_7^+$ + H →	No Reaction			$<1.00 \times 10^{-11}$	9201
c-$C_6H_7^+$ + H_2 →	No Reaction			$<1.00 \times 10^{-12}$	9201
$C_6H_7^+$ + C_2H_2 →	No Reaction			<I. OOX1O-13	8709
$C_6H_7^+$ + CH_3CCH →	$C_7H_7^+$	+ C_2I14	1.00		8429
$C_6H_7^+$ + C_4H_2 →	No Reaction			$<2.00X\ 10^{-11}$	8702

Table 3 (cont.)
Ien-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
$C_7H_7^+$	+ C_2H_2 →	$C_9H_9^+$	+ hv	1.00		8708
c-$C_7H_7^+$	t CH_3CCH →	$C_9H_8^+$	+ c113	0.10		8429
		$C_{10}H_9^+$	+ H_2	0.42		
		$C_{10}H_{11}^+$	+ hv	0.48		
$C_7H_7^+$	•t C_4H_2 →	$C_{11}H_9^+$	+ hv	1.00		8708
N^+	+ H_2 →	NH^+	+ }1	1.00	$5.00\times10^{-10}\pm20\%$	b
N^+	+ p-H_2 →	NH^+	+ H	1.00	3. OOX1O-10*3O%	8821
N^+	+ HD →	NH^+	+ D	0.25	$3.10\times10^{-10}\pm20\%$	b
		ND^+	+ }1	0.75		
N^+	+ D_2 →	ND^+	+ D	1.00	$1.50\times10^{-10}\pm20\%$	b
N^+	+ CH_4 →	CH_3^+	+ NH	0.53	$1.15\times10^{-9}\pm15\%$	d, b
		CH_4^+	+ N	0.05		
		HCN+	+ H_2 + 11	0.10		
		HCNH+	+ H_2	0.33		
N^+	+ C_2H_2 →	$C_2H_2^+$	+ N	0.70	1.5 OX1O-9 ±20%	d
		CNC+	+ H_2	0.15		
		CHNC+	+ H	0.15		
N^+	+ c2,114 →	$C_2H_2^+$	+ NH_2	0,10	$1.45\times10^{-9}\pm20\%$	d, 8007
		$C_2H_3^+$	+ Nfl	0.28		
		$C_2H_4^+$	+ N	0.30		
		HCN+	+ CH_3	0.13		
		HCNH+	+ c112	0.13		
		CHNC+	+ H_2 + H	0.08		
N^+	+ C_2H_6 →	$C_2H_5^+$	+ NH	0,10		d
		$C_2H_4^+$	+ NH_2	0.55		
		$C_2H_3^+$	+ NH_3	0,25		
		HCNH+	+ CH_4	0.10		
N^+	+ N_2 →	N^+	+ N_2	1.00	$2.55\times10^{-10}\pm40\%$	b
	→M	Adduct			-4.oox1o-29 (M= N_2)	8632
N^+	+ H_2O →	H_2O^+	+ N	1.00	2.70x $10^{-9}\pm20\%$	b
N^+	+ HCN →	HCN+	+ N	0.65	3.70x 10-9 ±20%	d, 9015
		CH+	+ N_2	0.35		
N^+	+ CH_3CN)	CH_3CN^+	+ N	0.50		d
		CH_2CN^+	+ NH	0.30		
		[$C_2H_2^+$	+ N_2 + H 1	0,20		
		[CN+	+ CH_2NH J			
N^+	+ C_2H_3CN →	$C_2H_3CN^+$	+ N	0.35		d
		$H_2C_3N^+$	+ NH	0.15		
		[CHCN+	+ CH_2N_2 1	0.25		
		[c-$C_3H_3^+$	+ N_2 J			
		[CN+	+ CH_3CN]	0.25		
		[$C_2H_2^+$	+ N_2 + CH J			
N^+	+ C_2N_2 →	C_2N^+	+ N_2	0.20	1.7 OX1O-9 ±30%	9501, 8515
		$C_2N_2^+$	+ N	0.80		
N^+	+ HC3N →	C_3H^+	+ N_2	0.38	4.2ox1O-9 ±20%	d, 8518

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
		$CHCCN^+$	+ N	0.63		
N^+	+ CO	→ C^+	+ NO	0.01	$5.60 \times 10^{-10} \pm 25\%$	b
		CO^+	+ N	0.88		
		NO^+	+ C	0.11		
NH^+	+ H_2	→ H_3^+	+ N	0.15	1.23x1 O-9 ±30%	b
		NH_2^+	+ H	0.85		
NH^+	+ CH_4	→ CH_5^+	+ N	0.10	$9.60 \times 10^{-10} \pm 20\%$	8010
		NH_2^+	+ CH_3	0.20		
		$HCNH^+$	+ H_2 + H	0.70		
NH^+	+ C_2H_4	→ $C_2H_2^+$	+ NH_3	0.10	1.5 OX1O-9 ±20%	8007
		$C_2H_3^+$	+ NH_2	0.25		
		$C_2H_4^+$	+ NH	0.25		
		$HCNH^+$	+ CH_3	0.20		
		$CHNH_2^+$	+ CH_2	0.10		
		CH_2CNH^+	+ H_2	0.10		
NH^+	+ N_2	→ N_2H^+	+ N	1.00	$6.50 \times 10^{-10} \pm 20\%$	b
NH^+	+ H_2O	→ NH_2^+	+ 011	0.25	3.5 OX1O-9±20%	8010
		NH_3^+	+ 0	0.05		
		H_2O^+	+ NH	0.30		
		H_3O^+	+ N	0.30		
		HNO^+	+ H_2	0.10		
NH^+	+ CO	→ HCO^+	+ N	0.45	$9.80 \times 10^{-10} \pm 20\%$	8010
		NCO^+	+ H	0.55		
NH_2^+	+ H_2	→ NH_3^+	+ H	1.00	$1.95 \times 10^{-10} \pm 50\%$	b
NH_2^+	+ CH_4	→ NH_3^+	+ CH_3	1.00	9.2 OX1O.1O*2O%	b
NH_2^+	+ C_2H_4	→ $C_2H_4^+$	+ NH_2	0.30	I.5OX1O-9 ±20%	8007
		$C_2H_5^+$	+ NH	0.20		
		$CH_2NH_2^+$	+ CH_2	0.30		
		$CH_2CHNH_2^+$	+ 11	0.20		
NH_2^+	+ N_2	→ No Reaction			<5. OOX1O-13	b
NH_2^+	+ H_2O	→ NH_3^+	+ 011	0.03	2.9 OX1O.9±20%	b
		NH_4^+	+ 0	0.04		
		H_3O^+	+ NH	0.94		
NH_2^+	+ CO	→ No Reaction			$<1.00 \times 10^{-11}$	8018
N_2^+	+ H	→ No Reaction			$<1.00 \times 10^{-11}$	9102
N_2^+	+ H_2	→ N_2H^+	+ H	1.00	2.oox1o-9 ±15%	b
N_2^+	+ D_2	→ N_2D^+	+ D	1.00	I.25x1o-9 ±20%	b

Table 3 (rent)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

			tions				Rat Coeffi		Refer
N_2^+	+ CH_4	→	CH_2^+	+ N_2 + H_2	0.05		1.14 X1 O-9 ±15%		d, b
			CH_3^+	+ N_2 + H	0.80				
			N_2H^+	+ CH_3	0.15				
N_2^+	+ C_2H_2	→	$C_2H_2^+$	+ N_2	0.37		4. 00x10^{-10} ±25%		d
			HCN$^+$	+ HCN	0.03				
			N_2H^+	+ C_2H	0.60				
N_2^+	+ C_2H_4	→	$C_2H_3^+$	+ N_2 + H	0.50		1.30x 10^{-9} ±25%		d
			$C_2H_2^+$	+ N_2 + H_2	0.20				
			HNC$^+$	+ HCN + 11,	0.10				
			HCNH$^+$	+ HCN + H	0.10				
			N_2H^+	-1 C_2H_3	0.10				
N_2^+	+ C_2H_6	→	$C_2H_6^+$	+ N_2			-I.3OX1O-9 ±25%		d
			$C_2H_5^+$	+ N_2 + H					
			$C_2H_4^+$	+ N_2 + H_2					
			$C_2H_3^+$	+ N_2 + H_2 + H					
			HCNH$^+$	+ CH_2NH_2					
N_2^+	+ N	→	No Reaction				<1.00 x10^{-11}		6804
*N_2^+	+ N_2	→	N_2^+	+ ● N2	1.00		5.80x10^{-10}±25%		b
		M →	Adduct				6.30x10^{-29}±25%		8632
							(M = N_2)		
N_2^+	+ H_2O	→	H_2O^+	+ N_2	0.79		2.4 OX1O-9±20%		b
			N_2H^+	-1 011	0.21				
N_2^+	+ HCN	→	HCN$^+$	+ N_2	1.00		3.90x10^{-10}±10%		d, 8101
N_2^+	+ CH_3CN	→	C} ICN$^+$	+ N_2 + H_2	0.20		2. 10x10^{-9}±30%		8804
			Cl H_2CN^+	+ N_2 + H	0.65				
			CH_2CNH^+	+ N_2	0.15				
N_2^+	+ C_2H_3CN	→	$C_2H_3^+$	+ N_2 + CN	0.10				d
			$C_2H_2^+$	+ N_2 + HCN	0.30				
			$H_2C_3N^+$	+ N_2 + H	0.35				
			HC_3N^+	+ N_2 + H_2	0.05				
			N_2H^+	+ H_2C_3N	-0.20				
N_2^+	+ C_2N_2	→	$C_2N_2^+$	+ N_2	1.00		9.30x10^{-10}±25%		9501, 8515
N_2^+	+ HC_3N	→	HC_3N^+	+ N_2	0.70		3.5 OX1O-9±25%		d, b
			N_2H^+	+ C3N	0.30				
N_2^+	+ CO	→	CO$^+$	+ N_2	1.00		7.30x10^{-11}±20%		b
N_2D^+	+ }1	→	N_2H^+	+ D	1.00		2.50x10^{-11}±20%		8503
N_2H^+	+ D	→	N_2D^+	+ }1	1.00		8.00x10^{-11}±20%		8503
N_2H^+	+ H_2	→	H_3^+	+ N_2	1.00		5. IOX1O-I8*8O%		b
		M →	Adduct				4.00 x1O-30		8632
							(M = H_2)		
N_2H^+	+ CH_4	→	CH_5^+	+ N_2	1.00		8.90x 10-10+30%		7005
N_2H^+	+ C_2H_2	→	$C_2H_3^+$	+ N_2	1.00		1.41x 1O.9±25%		7713
N_2H^+	t C_2H_6	→	$C_2H_5^+$	+ N_2 + H_2	0.87		1.3 OX1O-9 ±35%		8117
			$C_2H_7^+$	+ N_2	0.13				
N_2H^+	+ C_4H_2	→	$C_4H_3^+$	+ N_2	1.00		1.1 OX1O-9 ±30%		8645

Table 3 (cont)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions					Br. Ratio	Rate Coefficient*	Reference
● Nz,31+	+ N_2	→	N_2H^+	+ ● Nz	1.00	4.10x o-9 ±20%	b
		$\xrightarrow{M}$	Adduct				
N_2H^+	+ H_2O	→	H_3O^+	+ N_2	1.00	2.60x 10^{-9} ±10%	b
N_2H^+	+ HCN	→	$HCNH^+$	+ N_2	1.00	3.20x 10^{-9} ±20%	7605
N_2H^+	+ C_2N_2	→	$HC_2N_2^+$	+ N_2	1.00	1.20X 10^{-9} ±30%	8412
N_2H^+	+ HC_3N	→	$CHCCNH^+$	+ N_2	1.00	4.20x 10^{-9} ±20%	b
N_2H^+	+ CO	→	HCO^+	+ N_2	1.00	8.80x10^{-10}±25%	8006
1 H_2O^+	+ H_2	→	H_3O^+	+ H	.00	7.60x10^{-10}±15%	b
H_2O^+	+ CH_4	→	H_3O^+	+ c113	.00	1.12 X10-9 ±10%	b
H_2O^+	+ C_2H_4	→	$C_2H_4^+$	+ H_2O		.60x 10^{-9}±30%	8009
			$C_2H_5^+$	+ 011			
H_2O^+	+ C_2H_6	→	H_3O^+	+ C_2H_5	0.83	.60x10-9 ±20%	8117
			$C_2H_4^+$	+ H_2O + H_2	0.12		
			$C_2H_5^+$	+ H_2O + H	0.01		
			$C_2H_6^+$	+ H_2O	0.04		
H_2O^+	+ N	→	NO^+	+ H_2		1.90x10^{-10}±50%	8008
			HNO^+	+ H			
H_2O^+	•t N_2	→	No Reaction			<1.00x10^{-11}	7806
		$\xrightarrow{M}$	Adduct			I. 13x10^{-28} (M = H_2)	8632
H_2O^+	+ H_2O	→	H_3O^+	+ 011	1.00	1.85x 10^{-9} *15%	b
H_2O^+	+ HCN	→	H_3O^+	+ CN	<0.50	2.10 x I o-9 ±10%	8101
			$HCNH^+$	+ OH	>0.50		
H_2O^+	+ C_2N_2	→	$HC_2N_2^+$	+ 011	1.00	I. OOX1O-9 ±30%	8412
H_2O^+	+ CO	→	HCO^+	+ OH	1.00	4.25x10^{-10}±20%	b
H_3O^+	+ H_2	→	No Reaction			<5. OOX1O-15	7711
1130+	+ D_2	→	No Reaction			<1. OOX1O-12	7506
H_3O^+	+ CH_4	→	No Reaction			<I. OOX1O-2O	f
H_3O^+	+ C_2H_2		No Reaction			<1.00x10^{-16}	f
		$\xrightarrow{M}$	Adduct			8.00x 10^{-28} (M = He)	8935
H_3O^+	-1 C_2H_4	→	$C_2H_5^+$	+ 1120	1.00	2. OOX1O"12	f
		$\xrightarrow{M}$	Adduct			2.00 x10-27 (M = He)	8935
H_3O^+	+ C_2H_6	→	No Reaction			<1. OOX1O-2O	f
1 H_3O^+	+ C_3H_8	→	No Reaction			<1.oox1o-18	f
1 H_3O^+	+ C_4H_2	→	$C_4H_3^+$	+ H_2O	1.00	1.1 OX1O-9 ±30%	8645
H_3O^+	•t N	→	No Reaction			<1.00x10^{-11}	c

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
H_3O^+	+ N_2	→ No Reaction			<1. OOX1O-2O	f
H_3O^+	+ H_2O	→ No Reaction			$<1.00 \times 10^{-11}$	c
H_3O^+	+ H_2O	$\xrightarrow{M}$ Adduct			3.40×10^{-27} (M = N_2)	8632
H_3O^+	+ D_2O	→ Products		1.00	2..2o x1o-9 ±20%	8019
H_3O^+	+ HCN	→ $HCNH^+$	+ H_2O	1.00	3.80×10^{-9} ±15%	b
H_3O^+	+ CH_3CN	→ CH_3CNH^+	+ H_2O	1.00	4.50×10^{-9} ±15%	b
H_3O^+	+ HC_3N	→ $CHCCNH^+$	+ H_2O	1.00	3.9 OX1O-9 *30%	b
H_3O^+	+ CO	→ No Reaction			<1. OOX1O-11	c
CN^+	+ H	→ H^+	+ CN	1.00	6.40x10-lo	9603
CN^+	+ H_2	→ HCN^+	+ }1	0.50	1.1 OX1O-9 ±30%	b
		HNC^+	+ H	0.50		
CN^+	+ D_2	→ DCN^+	+ D	1.00	9.10×10^{-10} ±20%	b
CN^+	+ CH_4	→ CH_3^+	+ HCN	0.50	1.00×10^{-9} ±15%	b
		CH_4^+	+ CN	0.15		
		HCN^+	+ CH_3	0.15		
		$HCNH^+$	+ CH_2	0.10		
		CH_2CN^+	+ H_2	0.10		
CN^+	+ C_2H_2	→ $C_2H_2^+$	+ CN	0.90	-1.50×10^{-9} ±20%	8301
		$CHCCN^+$	+ H	0.10		
CN^+	+ C_2D_2	→ $C_2D_2^+$	+ CN	0.70	5.4 OX1O-10*3O%	8404
		$CDCCN^+$	● ID	0.30		
CN^+	+ C_2H_4	→ $C_2H_4^+$	+ CN	0.70	1.30×10^{-9} ±30%	b
		HCN^+	+ C_2H_3	0.25		
		$CHCCNH^+$	+ H_2	0.05		
CN^+	+ C_2H_6	→ $C_2H_3^+$	+ HCN + H_2	0.15	I.9OX1O.9 ±20%	8301
		$C_2H_4^+$	+ HCN + H	0.65		
		$C_2H_5^+$	+ HCN	0.20		
CN^+	+ C_4H_2	→ $C_4H_2^+$	+ CN	0.75	9.70×10^{-10} *30%	8645
		HC_5N^+	+ 11	0.25		
CN^+	+ N	→ N_2^+	+ C	1.00	6.50×10^{-10}	e
CN^+	+ N_2	→ No Reaction			$<4.30 \times 10^{-12}$ ±30%	b
CN^+	+ H_2O	→ H_2O^+	+ CN	0.10	3.2 OX1O-9 ±20%	8301
		HCN^+	+ OH	0.50		
		$HCNH^+$	+ 0	0.15		
		HCO^+	+ NH	0.05		
		$HNCO^+$	+ H	0.20		
CN^+	+ D_2O	→ D_2O^+	+ CN	0.40	2.10 X10.9 ±30%	8404
		DCN^+	+ OD	0.40		
		DCND+	+ O	0.10		
		$DNCO^+$	+ D	0.10		
CN^+	+ HCN	→ HCN^+	+ CN	0.83	2.7 OX1O-9 ±20%	b
		$C_2N_2^+$	+ H	0.17		

Table 3 (rent.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
CN^+	+ CD_3CN	→	CD_3^+ + C_2N_2	0.20	3.4 OX1O-9 *30%	8404
			$C_2D_3^+$ + CN_2	0.10		
			CD_2CN^+ + DCN	0.20		
			CD_2CND^+ + CN	0.50		
CN^+	+ C_2N_2	→	C_2N^+ + CN_2	0.03	1.75x 10-9 ±30%	b
			$C_2N_2^+$ + CN	0.93		
			C_3N^+ + N_2	0.05		
CN^+	+ HC_3N	→	C_3N^+ + HCN	0.20	4.60x 10^{-9}±20%	b
			C}ICCN$^+$ + CN	0.80		
CN^+	+ CO	→M	CO^+ + CN	1.00	4.40x 10^{-10}±60%	b
			Adduct		2.50x10-lo (in 0.34 Torr of He)	8404
HCN^+	+ D	→	D^+ + HCN	1.00	3.70x10^{-11}±50%	7901
HCN^+	+ H_2	→	$HCNH^+$ + H	1.00	8.80x10^{-10}±20%	b
HCN^+	+ CH_4	→	$C_2H_3^+$ + NH_2	0.10	1.27x 10^{-9}±15%	b
			$HCNH^+$ + CI13	0.90		
HCN^+	+ C_2H_2	→	$C_2H_2^+$ + HCN	>0.85	1.35 X1 O-9 ±45%	b
			$C_2H_3^+$ + CN	<0.15		
			$CHCCNH^+$ + H	<0.10		
HCN^+	+ N_2	→	No Reaction		<1.00x10^{-11}	8101
HCN^+	+ H_2O	→	H_2O^+ + HCN	-0.50	3.6 OX1O.9±10%	8101
			H_3O^+ + CN	-0.50		
			$HCNH^+$ + 011	<0.05		
HCN^+	+ HCN	→	$HCNH^+$ + CN	1.00	I.45X1O-9 ±45%	b
HCN^+	+ HC_3N	→	$CHCCN^+$ + HCN	0.52	4.6 OX1O-9±20%	b
			$CHCCNH^+$ + CN	0.48		
HCN^+	+ C_2N_2	→	$HC_2N_2^+$ + CN		1.1x IO-9 *1O%	9501
HCN^+	+ CO	→	HCO^+ + CN	0.30	4.60x10^{-10}±20%	b
			HNC^+ + CO	0.70		
HNC^+	+ H_2	→	$HCNH^+$ + H	1.00	7.00x10^{-10}±30%	9116
HNC^+	+ CH_4	→	$HCNH^+$ + cl 13	1.00	1.1 OX1O-9 ±30%	9116
HNC^+	+ C_2H_2	→	$C_2H_2^+$ + HCN	-0.40	1.50 x10^{-9}±30%	9116
			$CHCCNH^+$ + 11	-0.60		
HNC^+	+ CO	→	No Reaction		<1.00x10^{-12}	b
$HCNH^+$	+ H	→	No Reaction		<2.0x10^{-11}	c
$HCNH^+$	+ H_2	→	No Reaction		<4. OOX1O-13	7711
$HCNH^+$	+ D_2	→	No Reaction		<2.50x10^{-12}	7701
$HCNH^+$	+ CH_4	→	No Reaction		<1.0x10^{-20}	f

Table 3 (WIN)
1oIVMo1CCUIC Reactions Relavent to Titan's Atmosphere

		Reactions		Br. Ratio	Rate Coefficient*	Reference
$HCNH^+$	+ C_2H_2	→ No Reaction			<1. OX1O-2O	f
		$\xrightarrow{M}$ Adduct			5.00x 10^{-29} (M = He)	8935
$HCNH^+$	+ C_2H_4	→ No Reaction			<1. OX1O-15	f
		$\xrightarrow{M}$ Adduct			7.00x 10^{-27} (M = He)	8935
$HCNH^+$	+ C_2H_6	→ No Reaction			<2.0x10^{-11}	d
$HCNH^+$	+ C4112	→ $C_4H_3^+$	+ HCN	1.00	1.60x1 0-9 ±30%	9118, 8645
$HCNH^+$	+ N_2	→ No Reaction			<1. OX1O-2O	f
$HCNH^+$	+ 1120	→ H_3O^+	+ HCN	1.00	8.8 OX1O-13*4O%	7809
$HCNH^+$	+ HCN	→ No Reaction			<2, OX1O-11	c
		$\xrightarrow{M}$ Adduct			1. OOX1O-9 (in 0.30 Torr of He)	?
$HCNH^+$	+ CH_3CN	→ CH_3CNH^+	+ HCN	1.00	3.80x 10-9 ±20%	8929
$HCNH^+$	+ HC_3N	→ CHCCNH$^+$	+ HCN	1.00	3.40 x10^{-9}±30%	7911
CNC^+	+ H_2	→ No Reaction			<1.00x10^{-13}	b
CNC^+	+ CH_4	→ $C_2H_3^+$	+ HCN		4.20x10^{-12}±20%	b
		CHCCNH$^+$	+ H_2			
CNC^+	+ C_2H_2	→ C_3H^+	+ HCN	0.92	8.00x10^{-10}±40%	b
		$HCNH^+$	+ C3	0.08		
		HC_4N^+	+ 11	?		
CNC^+	+ C_2H_4	→ $C_2H_4^+$	+ C_2N	0.10	1.3 OX1O-9 *20%	8301
		$C_3H_3^+$	+ HCN	0.30		
		CH_2CN^+	+ C_2H_2	0.50		
		$H_2C_4N^+$	+ H_2	0.10		
CNC^+	+ C_2H_6	→ $C_2H_3^+$	+ CH_3CN	0.10	1.20 X10-9 ±20%	8301
		$C_2H_5^+$	+ HC_2N	0.25		
		$C_3H_3^+$	+ HCN + H_2	0.30		
		$C_3H_5^+$	+ HCN	0.10		
		CH_2CN^+	+ C_2H_4	0.25		
CNC^+	+ C_4H_2	→ C_5H^+	+ HCN	0.60	1.30 x10^{-9}±30%	8645
		$C_4H_2^+$	+ CNC	0.20		
		Adduct		0.20		
CNC^+	+ N_2	→ No Reaction			<1.00x10^{-13}	b
CNC^+	+ H_2O	→ CHCN$^+$	+ 011	0.25	7.00x10^{-11}±40%	b
		HCO^+	+ HCN	0.7s		
CNC^+	+ HCN	→ No Reaction			<3.00X 10^{-11}	b
		$\xrightarrow{M}$ Adduct			4.2 OX1O-10 (in 0.30 Torr of He)	8802
CNC^+	+ CH_3CN	→ $C_2H_3^+$	+ C_2N_2	1.00	4.1 OX1O-9 *20%	8012
CNC^+	+ C_2N_2	→ No Reaction			<1.00x10^{-11}	8301
CNC^+	+ HC_3N	→ C_3H^+	+ C_2N_2	1.00	3.30x 10^{-9} ±20%	b
CNC^+	+ CO	→ No Reaction			<1.00x10^{-11}	8301

Table 3 (cont.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient*	Reference
CCN^+	+ H_2	→	$HCNH^+$ + H	0.90	9. OOX1O"1O*4O%	8802
			CH_2CN^+	0.10		
CCN^+	+ CH_4	→	$C_2H_3^+$ + }ICN	0.60	7. OOX1O.1O*4O%	8802
			$HCNH^+$ + C_2H_2	0.10		
			$CHCCNH^+$ + H_2	0.30		
CCN^+	+ C_2H_2	→	C_3H^+ + HCN	0.92	1.60×10^{-9} ±40%	8802
			$HCNH^+$ + C3	0.08		
CCN^+	+ N_2	→	No Reaction		<1. OOX1O-I3	8802
CCN^+	+ H_2O	→	$HCNH^+$ + CO	0.08	1.63x 10-9 ±40%	8802
			HCO^+ •t HCN	0.92		
CCN^+	+ HCN	$\xrightarrow{M}$	Adduct	1.00	4.20x10-lo (in 0.30 Torr of He)	8802
C_3N^+	+ H_2	→	$CHCCN^+$ + H	0.90	9.10×10^{-10} ±20%	8518
			C} ICCNH$^+$	0.10		
C} ICCN$^+$	+ H_2	→	$C_2H_2^+$ + HCN	0.37	4.45×10^{-12} ±80%	b
			$CHCCNH^+$ + H	0.63		
$CHCCN^+$	+ CH_4	→	$C_3H_4^+$ + HCN	0.10	5.90X 0-10 ±30%	8616
			CH_2CNH^+ + C_2H_2	0.50		
			$CHCCNH^+$ + CH_3	0.30		
$CHCCN^+$	+ C_2H_2	→	$C_2H_2^+$ + HC_3N	0.20	6.40x 0-10 ±30%	8616
			$C_4H_2^+$ + HCN	0.80		
$CHCCN^+$	+ C2114	→	$C_2H_4^+$ + HC_3N	0.80	6.70x 0-10 ±30%	8616
			$CHCCNH^+$ + C_2H_3	0.20		
$CHCCN^+$	+ C_4H_2	→	$C_4H_2^+$ + HC_3N	1.00	8.90x 0-10 ±30%	8616
$CHCCN^+$	+ N_2	→	No Reaction		$<1.00 \times 10^{-11}$	c
$CHCCN^+$	+ H_2O	→	$CHCCNH^+$ + 011	1,00	6.70×10^{-10} ±30%	8616
$CHCCN^+$	+ HCN	→	Adduct	1.00	8.90×10^{-10} ±30%	8616
$CHCCN^+$	+ HC_3N	→	HC_5N^+ + HCN	0.90	1.30×10^{-9} ±20%	9115
			$HC_6N_2^+$ + H	0.05		
			$H_2C_6N_2^+$ + hv	0.05		
		$\xrightarrow{M}$	Adduct		1.2 OX1O-22 (M= HC_3N)	9115
$CHCCN^+$	+ CO	$\xrightarrow{M}$	Adduct	1.00	3.4 OX1O-11 (in 0.31 Torr of He)	8616
$CHCCNH^+$	+ 11	→	No Reaction		$<1.00 \times 10^{-11}$	c
$CHCCNH^+$	+ H_2	→	No Reaction		<1. OOX1O-13	8616
$CHCCNH^+$	+ C_2H_4	→	$H_5C_5N^+$ + 11		<1.3 OX1O-9	d
C} ICCNH$^+$	+ N_2	→	No Reaction		<1. OX1O-2O	f

Table 3 (rent.)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions					Br. Ratio	Rate Coefficient*	Reference
C}ICCNH+	+ HC_3N	-›	No Reaction			<1.00%10-11	c
CHCCNH+	+ CO	—›	No Reaction			<1. 00x10-12	b
$C_2H_3CN^+$	+ C_2H_3CN	- - ›	$C_2H_3CNH^+$	+ C2112CN	0.95	1.9 OX1O-9 *lo%	d
			$H_5C_3N^+$	+ HCN	0.05		
			$(C_2H_3CN)_2^+$				
$C_2H_3CNH^+$	+ C_2H_3CN	_M,	$(C_2H_3CN)_2H^+$			1.25x10-23±20% (M= C_2H_3CN)	d
			(C2313CN)211+			1.55x10-24±20% (M = He)	d
HC_5N^+	+ C_2H [4		$H_2C_5N^+$	+ C_2H_3	0.75	1,20 X10-9 ±10%	d
			$H_3C_7N^+$	+ H_2	0.05		
			$H_5C_7N^+$		0.20		
$C_2N_2^+$	+ H	- ›	HNC^+	+ CN	0.80	6.2x1 O-10	9603
		- ›	C211+	+ N_2	0.20		
$C_2N_2^+$	+ H_2	- ›	$HC_2H_2^+$	+ H	1.00	9.0x10-10	9603
$C_2N_2^+$	+ C_2H_2	- ›	$C_2H_2^+$	+ C_2N_2	0.50	2. OOX1O-1%IO%	d
			$HC_4N_2^+$	+ H	0.35		
			$C_4N_2^+$	+ 11_2	0.15		
$C_2N_2^+$	+ C_4H_2	- ›	C_4H2^+	+ C_2N_2	0.90	1.20 X10-9 ±30%	8645
			HC_5N^+	+ HNC	0.10		
$C_2N_2^+$	+ HCN	)	Products			2.40x 10-9±10%	d
$C_2N_2^+$	+ C_2N_2	›	No Reaction			<1.00x10-11	9501
		_M›	$C_4N_4^+$			1.70x10-23±10% (M = C_2N_2)	9501
			$C_4N_4^+$			2.20x10-24±10% (M = N_2)	9501
CO^+	+ H	– ›	H+	+ CO	1.00	3.3 OX IO-10	8635
CO^+	+ }1	›	H^+	+ CO	1.00	7.50x10-10±30%	8403
CO^+	+ D	- ›	D^+	+ CO	1.00	9.00x10-11±20%	7901
CO^+	+ H_2	›	HCO^+	+ H	0.52	1.40 x10-9±15%	b
			HOC^+	+ }1	0.48		
CO^+	+ D_2	›	DCO^+	+ D	1.00	9.60x10-10±10%	7901
CO^+	+ CH_4	›	CH_4^+	+ CO	0.67	1.34x lo-9 *1O%	b
			HCO^+	+ CH_3	0.28		
			CH_3CO^+	+ H	0.05		
CO^+	+ C_2H_2	—+	$C_2H_2^+$	+ CO	1.00	4. 10x10-10	7209
CO^+	+ N	-)	NO^+	+ C	1.00	~1.00x10-11	e, 7201

Table 3 (cont)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions					Br. Ratio	Rate Coefficient*	Reference
CO^+	+ N_2	$\xrightarrow{M}$	Adduct			2.1o x10-29 (M = He)	8632
CO^+	+ H_2O	→	H_2O^+	+ CO	0.65	2.4 OX1O-9±10%	b
			HCO^+	•t 011	0.35		
CO^+	+ HCN	→	HCO^+	+ CN	<0.10	3.4 OX1O-9±10%	8101
			HCN^+	+ CO	>0.90		
CO^+	+ Cl I_3CN	→	CH_2CN^+	+ H + CO	0.25	3.00 x10^{-9}±30%	8804
			c112CN1 I+	+ CO	0.75		
CO^+	+ HC3N	→	C}ICCN+	+ CO	1.00	3. 10x10^{-9}±25%	b
CO^+	+ CO	$\xrightarrow{M}$	Adduct			1.40x10^{-28} (M = CO)	8632
HCO^+	+ D	→	DCO^+	+ H	1.00	4.25x10^{-11}±20%	b
HCO^+	+ H_2	→	No Reaction			<2.00 x10.14	b
		$\xrightarrow{M}$	Adduct			8.3 OX1O-31 (M = He)	8632
HCO^+	+ D_2	→	DCO^+	+ HD	1.00	1.80x10^{-11}±50%	7701
HCO^+	+ CH_4	→	No Reaction			<1.00x 10^{-13}	b
HCO^+	+ C_2H_2	→	$C_2H_3^+$	+ CO	1.00	I.36x1O-9 ±25%	7713
HCO^+	+ C_2H_6		$C_2H_7^+$	+ CO	1.00	I.2OX1O-10*2O9O	8117
HCO^+	+ N_2	→	No Reaction			*<4. OOX1O.14*	7805, f
1ICO+	+ H_2O		H_3O^+	+ CO	1.00	2.60x 10^{-9} ±30%	b
HCO^+	+ HCN	→	$HCNH^+$	+ CO	1.00	3.5 OX1O-9±15%	b
HCO^+	+ c113CN	→	CH_3CNH^+	+ CO	1.00	4. 10x10^{-9}±25%	7605
HCO^+	+ HC_3N	→	CHCCNH+	+ CO	1.00	3.80x 10^{-9}±20%	b
● 1ICO+	+ CO	→	H CO+	+ *CO	1.00	2.60x10^{-10}±20%	8005
HCO^+	● tCo	→	No Reaction			*<4. OOX1O-14*	7805
		$\xrightarrow{M}$	Adduct			2.40x10-3° (M= CO)	8632
DCO+	+ H	→	HCO^+	+ D	1.00	1.50x10^{-11}±30%	b
110CY	+ H_2	→	H_3^+	+ CO	0.57	4.7 0x10^{-10}±20%	b
			HCO^+	+ H_2	0.43		
DOC+	+ H_2	→	H_2D^+	● tCi3	0.57	6.20x10^{-10}±20%	8711
			HCO^+	+ HD	0.43		
HOC+	+ CH_4	→	CH_5^+	+ CO	1.00	1.1 OXIO"9±20%	8711
HOC+	+ N_2	→	N_2H^+	+ CO	1.00	6.7 OX IO-10*2O%	8505
HOC+	+ CO	→	HCO^+	+ CO	1.00	6.00x10^{-10}±20%	8711

Table 3 (cont)
Ion-Molecule Reactions Relavent to Titan's Atmosphere

Reactions				Br. Ratio	Rate Coefficient[a]	Reference
CH_2OH^+	+ H_2	→ No Reaction			$<2.00 \times 10^{-14}$	b
CH_2OH^+	+ CH_4	→ No Reaction			$<4.00 \times 10^{-14}$	7805
CH_2OH^+	+ C_4H_2	→ $C_4H_3^+$	+ H_2CO	1.00	$9.30 \times 10^{-10} \pm 20\%$	8702
CH_2OH^+	+ N_2	→ No Reaction			$<4.00 \times 10^{-14}$	7805
CH_2OH^+	+ H_2O	→ H_3O^+	+ H_2CO	1.00	$2.30 \times 10^{-10} \pm 10\%$	b
CH_2OH^+	+ HCN	→ $HCNH^+$	+ H_2CO	1.00	1.3×10^{-9} *30%	b
CH_2OH^+	+ CO	→ No Reaction			$<4.00 \times 10^{-14}$	7711
NO^+	+ HCN	→ No Reaction			$<8.00 \times 10^{-11}$	d

Table 3 (cont.)
Inn-Molecule Reactions Relavent to Titan's Atmosphere

References Used in the Table of Reactions

a The units of the reaction rate coefficients are $cm^3 s^{-1}$ for the bimolecular reactions. The termolecular reactions are noted by a reaction arrow with an M over it, in th is case the units are $cm^6 s^{-1}$. Many of the termolecular reaction rate coefficients are given as saturated bimolecular rates, these are noted by she additional pressure information discribing the saturat ion condition.
b V. G. Anicich, J. Phys. Chem. Ref. Data, 22, 1469 (1993), Evaluated citation, see reference for original citations.
c No reaction channel that is thermodynamically allowed
d Unpublished work of V. G. Anicich and M. J. McEwan 1995.
e Preliminary nitrogen atom work of Graham and M. J. McEwan
f Calculated reactions rate coefficients for the proton transfer reaction. These were calculated from using the reverse proton transfer reactions rate coefficient and the endothermisity of the reaction.

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