PHYSICAL ATMOSPHERIC PARAMETERS FOR LATE-TYPE STARS*

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ABSTRACT

For a gas mixture, the relation between total gas pressure, partial pressure of atomic hydrogen, mean molecular weight, and several other auxiliary quantities has been determined as a function of electron pressure and $\theta = 5040/T$, for three hydrogen-to-helium abundance ratios. The effect of molecular hydrogen has been incorporated.

Rosa (1948) has given, for constructing stellar atmospheres, tables of total gas pressure, mean number of free electrons per nuclei, and effective molecular weight, for a given chemical composition, as a function of temperature T or $\theta = 5040/T$ and electron pressure p_e. Her tables extend from $\theta = 0.07$ to $\theta = 1.4$, and $\log_{10} p_e = -2.0$–5.0. However, for the construction of atmospheric models for late-type stars, not only do these tables need to be extended to higher values of θ or lower temperatures and lower electron pressures, but the effect of molecular hydrogen, which becomes important at lower temperatures (Wildt 1934, 1957; Vardya 1960; Vardya and Wildt 1960), has also to be incorporated. The purpose of this paper is to provide such tables of total gas pressure P, partial pressure of atomic hydrogen p_H, effective molecular weight μ, and several other quantities, as a function of θ and $\log p_e$. The range of θ is from 1.0 to 2.0, and that of $\log p_e$ from -5.0 to 2.0. The main assumptions adopted in this work are as follows:

1. It is assumed that each constituent of the gas mixture behaves as a perfect gas.

2. The population of the excited states of atomic and negative hydrogen and of metals have been deemed negligible.

3. The metals have been considered only in neutral and singly ionized states, and helium in only the neutral state.

4. Extremely rare ions like HeH^+ and H_3^+ have been discarded.

Besides hydrogen and helium, sixteen other elements, which we shall abbreviate and call "metals," have been included. The choice of the metals has been based on their first ionization potentials and their abundances. Table 1 gives the first ionization potential χ, statistical weights of the ground levels of the neutral atom, g_0, and of singly ionized ion, g_1, molecular weight, and the logarithm of relative abundance of nuclei, $\log N$,[1] taking that of hydrogen as 8.0, of all the elements considered. The metals in the table are listed with increasing ionization potential. The values of χ, g_0, g_1, and molecular weight have been taken from Unsöld (1957). The values of $\log N$ for metals have been taken from the compilation given by Aller (1959) for the sun, except for the low-ionization-potential metals, for which Miss Edith A. Müller kindly provided the latest solar abundances. From Table 1, one easily obtains the hydrogen-to-metals abundance ratio, A, as 497.1. As B, the hydrogen-to-helium abundance ratio, is still rather uncertain, two sets of tables have been constructed for two hydrogen-to-helium abundance ratios, 16/1 and 8/1 and, as a special case, a third set with no helium ($B = \infty$) has also been computed. These hydrogen-to-helium abundance ratios have been taken, following the earlier work of the author (1960).

Hydrogen has been considered in five states—H_2, H_2^+, H^-, H, and H^+. The dissociation

[1] In this paper all abundances are by number.

equilibrium constant for molecular hydrogen K (H_2) can be represented by the following polynomial (Vardya 1960):

$$\log_{10} K\,(H_2) = \log_{10} \frac{p_H^2}{p_{H_2}} = 12.533505 - 4.9251644\,\theta$$

$$+ 0.056191273\,\theta^2 - 0.0032687661\,\theta^3 . \tag{1}$$

Here p_H denotes the partial pressure of atomic hydrogen, and p_{H_2} that of molecular hydrogen.

TABLE 1

CHEMICAL COMPOSITION OF GAS MIXTURE

Element	x	g_0	g_1	Molecular Weight	$\log_{10} N$
H	13 59	2	1	1 008	8 0
He	24 58	1	2	4 003	....
K	4 34	2	1	39 10	0 70
Na	5 14	2	1	23 00	2 30
Al	5 98	6	1	26 97	2 20
Ca	6 11	1	2	40 08	2 15
Cr	6 76	7	6	52 01	1 36
Ti	6 83	21	28	47 90	0.68
Mn	7 43	6	7	54 93	0 90
Ni	7 63	21	10	58 69	1 91
Mg	7 64	1	2	24 32	3 40
Fe	7 90	25	30	55 85	2 57
Si	8 15	9	6	28 06	3 60
S	10 36	9	4	32 07	3 17
C	11 26	9	6	12 01	4 56
O	13 61	9	4	16 00	5 00
N	14 54	4	9	14 01	3 98
Ne	21 56	1	6	20 18	4 67

Following Mayer and Mayer (1940) and using the spectroscopic constants as given in the compilation by Herzberg (1950), the equilibrium constant for H_2^+ can be expressed, after simplifying assumptions, as

$$\log_{10} K\,(H_2^+) = \log_{10} \frac{p_H p_{H^+}}{p_{H_2^+}} = 11.44175 - 0.651441\,\ln_e\theta - 2.648\,\theta$$

$$+ 0.434294 \left\{ \ln_e(e^{0.6201760} - 1) - 0.620176\,\theta - \ln_e\left[1 + 2.78622 \times 10^{-3}\,\theta \right.\right. \tag{2}$$

$$\left.\left. + \frac{0.161079}{\theta} + \frac{0.046980}{(e^{0.6201760} - 1)} + \frac{3.39317 \times 10^{-2}\,\theta}{(e^{0.6201760} - 1)^2} \right] \right\} .$$

For ease in computation, it was expressed in the following polynomial form:

$$\log_{10} K\,(H_2^+) = 11.206998 - 2.7942767\,\theta - 0.079196803\,\theta^2$$

$$+ 0.024790744\,\theta^3 , \tag{3}$$

[2] I am grateful to Dr. R. Wildt for lending me his notes regarding the calculation of K (H_2^+).

the percentage root-mean-square error of this polynomial representation being 0.022 for $0.3 \leq \theta \leq 2.0$.

The equilibrium constant for H^- is given by:

$$\log_{10} K(H^-) = \log_{10} \frac{p_H p_e}{p_{H^-}} = -0.747\,\theta + 2.5\,\log_{10} T + 0.1249 \,. \tag{4}$$

The ionization equilibrium constants for atomic hydrogen as well as for metals have been computed by means of the following equation, with appropriate values of the constants taken from Table 1:

$$\log_{10} K = -\theta\chi + 2.5\,\log_{10} T + \log_{10} \frac{2\,g_1}{g_0} - 0.4772 \,. \tag{5}$$

It should be noted, that for atomic hydrogen as well as for metals, we have replaced the partition functions by the statistical weights of the ground states.
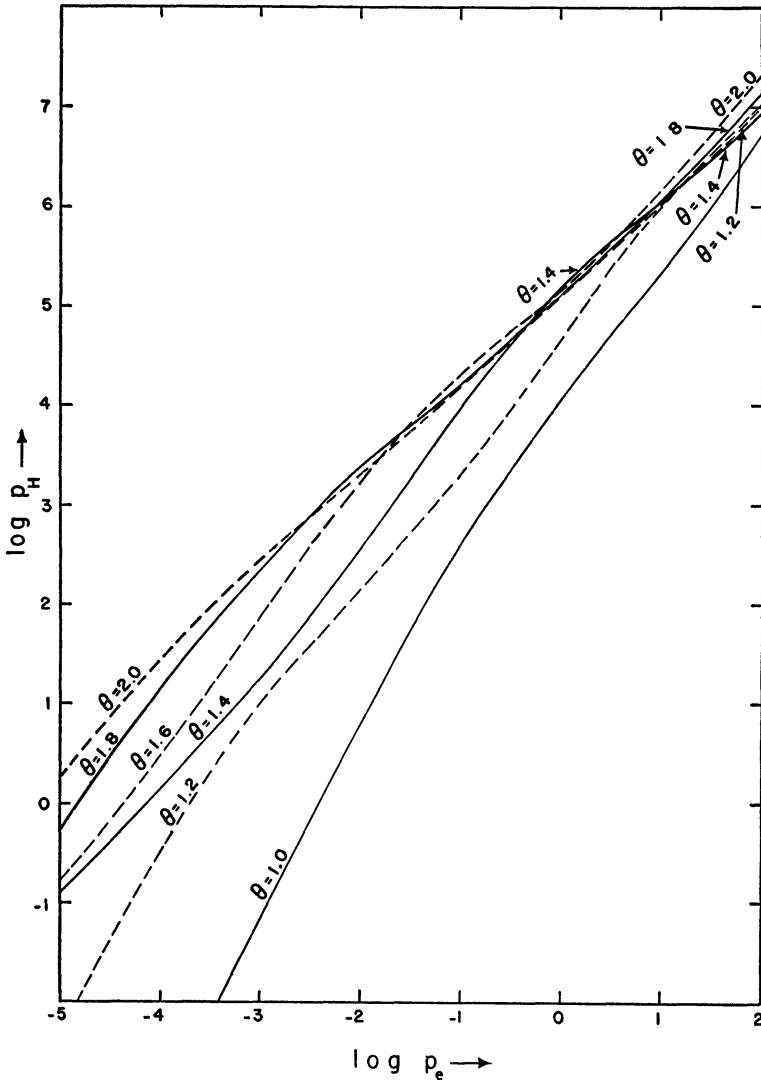

FIG. 1.—Plot of $\log p_H$ versus $\log p_e$ for various values of θ

Helium has been considered only in the neutral state. For the temperature and electron-pressure range with which we are concerned here, one can safely neglect the ionization of helium.

It is of some interest to look into the equilibrium constants for metals, with a view to representing all the metals combined by a single equilibrium constant K (M), of a fictitious metal M, with an abundance equal to the total abundance of all the metals taken together.

Let λ_i be the fractional abundance, by number, of the metal i, such that

$$\Sigma \lambda_i = 1, \text{ summed over all the metals .} \tag{6}$$

Let K_i and μ_i denote the equilibrium constant and molecular weight, respectively, of the metal i. Then, properly to represent the contribution of metals to the effective molecular weight, the molecular weight of the fictitious metal M will be given by

$$\mu_M = \sum_i \lambda_i \mu_i . \tag{7}$$

Considering that, for a given temperature and pressure, the metal M should contribute the same number of electrons as the sum of the contributions of all the metals considered individually, one easily obtains

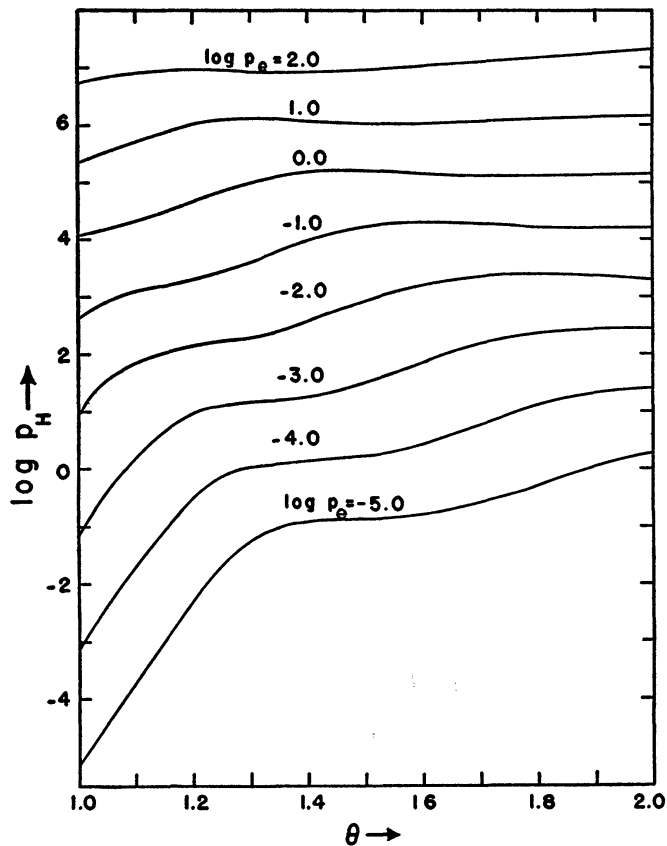$$K(M) = \frac{p_e}{\left\{ 1/ \sum_i [\lambda_i K_i/ (p_e + K_i)] \right\} - 1} . \tag{8}$$

FIG. 2.—Plot of log p_H versus θ for various values of log p_e

Note that, whereas the various K_i's are functions of T only, K (M) is a function of both T and p_e. However, it can be shown that, in two extreme cases, K (M) reduces to functions of temperature only:

Case 1: If $p_e \gg K_i$, for all i, K (M) $\Rightarrow \sum_i \lambda_i K_i$ (straight mean). (9)

Case 2: If $p_e \ll K_i$, for all i, K (M) $\Rightarrow \left(\sum_i \dfrac{\lambda_i}{K_i} \right)^{-1}$ (harmonic mean). (10)

Tables 2–12 tabulate the values of $\log_{10} P$, $\log_{10} N_{H_2}$, $\log_{10} N_H$, $\log_{10} N_H N_{H^+}$, μ, and $\log_{10} K$ (M) as a function of $\log_{10} p_e$ for $\theta = 1.0$–2.0 in steps of 0.1 in θ for a chemical composition of $A = 497.1$, and $B = \infty$ (no helium). Here N_{H_2}, N_H, and N_{H^+} denote the number per cm^3 of H_2, H, and H^+. The presence of helium alters only the values of $\log_{10} P$ and μ, as we are not taking into account the ionization of helium. Tables 13 and 14 give the values of $\log_{10} P$, and Tables 15 and 16 those of μ, as a function of $\log_{10} p_e$ and θ, for $B = 16/1$ and $8/1$, respectively. The hydrogen-to-metals abundance ratio has been, taken the same in all the calculations.

Figure 1 displays the relation between $\log_{10} p_H$ and $\log_{10} p_e$ for several values of θ, and Figure 2 gives the relation between $\log p_H$ versus θ for constant values of electron pressures. Figure 1 and 2 do not depend on any particular value of the hydrogen-to-helium
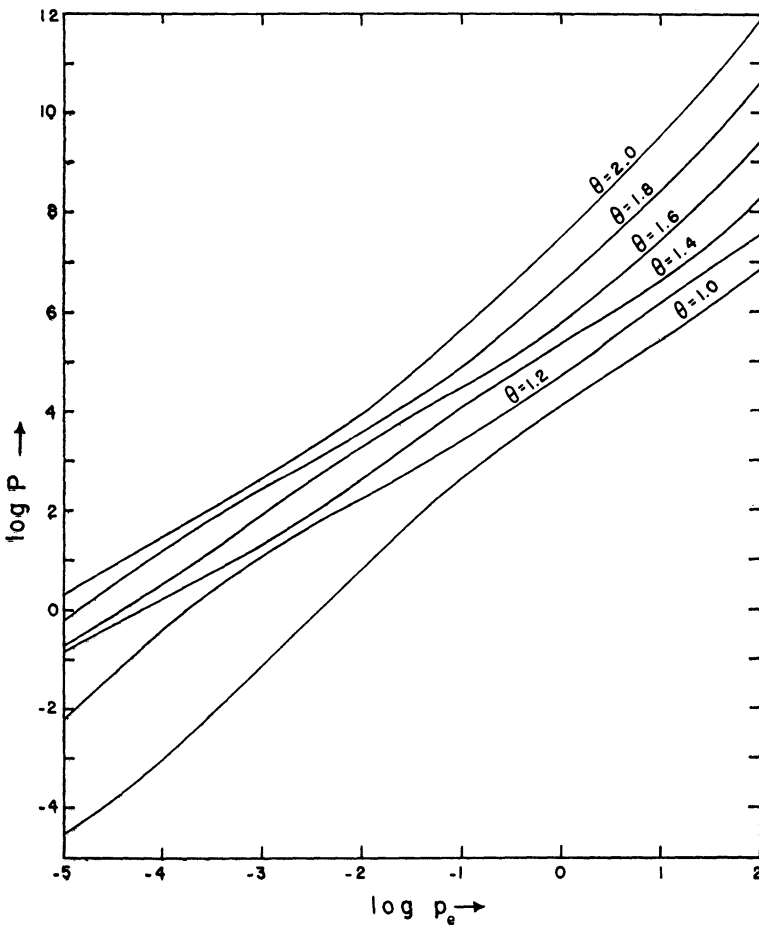

Fig 3.—Plot of log P versus log p_e for various values of θ for $B = 8/1$

TABLE 2

1/A = 0.00201		1/B = 0.		THETA = 1.00			
LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-5.18472	-4.57592	-5.84992	6.99607	14.17609	0.64804	-4.95230
-4.800	-4.78479	-4.31744	-5.05005	7.39600	14.77596	0.69737	-4.86075
-4.600	-4.38490	-4.03841	-4.25027	7.79589	15.37574	0.75431	-4.76574
-4.400	-3.98508	-3.73683	-3.45063	8.19571	15.97539	0.81380	-4.66058
-4.200	-3.58536	-3.41292	-2.65120	8.59543	16.57481	0.86984	-4.54097
-4.000	-3.18582	-3.06906	-1.85211	8.99497	17.17390	0.91771	-4.40574
-3.800	-2.78653	-2.70897	-1.05353	9.39426	17.77248	0.95528	-4.25666
-3.600	-2.38762	-2.33675	-0.25572	9.79317	18.37029	0.98288	-4.09746
-3.400	-1.98929	-1.95615	0.54095	10.19150	18.96696	1.00217	-3.93284
-3.200	-1.59176	-1.57019	1.33600	10.58903	19.56202	1.01520	-3.76777
-3.000	-1.19532	-1.18122	2.12889	10.98547	20.15490	1.02380	-3.60714
-2.800	-0.80023	-0.79092	2.91907	11.38056	20.74508	1.02940	-3.45529
-2.600	-0.40670	-0.40044	3.70613	11.77409	21.33214	1.03302	-3.31539
-2.400	-0.01483	-0.01052	4.48986	12.16596	21.91587	1.03534	-3.18847
-2.200	0.37524	0.37832	5.27001	12.55603	22.49603	1.03684	-3.07262
-2.000	0.76316	0.76544	6.04584	12.94395	23.07185	1.03780	-2.96315
-1.800	1.14799	1.14977	6.81550	13.32878	23.64151	1.03842	-2.85372
-1.600	1.52806	1.52952	7.57564	13.70885	24.20166	1.03881	-2.73801
-1.400	1.90084	1.90209	8.32120	14.08162	24.74721	1.03907	-2.61130
-1.200	2.26298	2.26411	9.04549	14.44377	25.27150	1.03923	-2.47120
-1.000	2.61067	2.61172	9.74146	14.79146	25.76687	1.03934	-2.31778
-0.800	2.94031	2.94131	10.40015	15.12110	26.22616	1.03941	-2.15297
-0.600	3.24965	3.25063	11.01882	15.43044	26.64483	1.03948	-1.97974
-0.400	3.53869	3.53966	11.59691	15.71948	27.02292	1.03954	-1.80140
-0.200	3.81006	3.81104	12.13964	15.99084	27.36565	1.03963	-1.62122
-0.000	4.06839	4.06942	12.65631	16.24918	27.68232	1.03976	-1.44230
0.200	4.31931	4.32042	13.15815	16.50010	27.98416	1.03998	-1.26760
0.400	4.56825	4.56950	13.65602	16.74904	28.28203	1.04035	-1.09970
0.600	4.81953	4.82105	14.15858	17.00032	28.58459	1.04101	-0.94047
0.800	5.07578	5.07780	14.67108	17.25657	28.89710	1.04221	-0.79077
1.000	5.33791	5.34087	15.19535	17.51870	29.22136	1.04444	-0.65044
1.200	5.60570	5.61041	15.73093	17.78649	29.55695	1.04859	-0.51901
1.400	5.87844	5.88644	16.27640	18.05923	29.90241	1.05638	-0.39647
1.600	6.15468	6.16891	16.82888	18.33547	30.25489	1.07089	-0.28343
1.800	6.43111	6.45688	17.38174	18.61189	30.60775	1.09723	-0.18030
2.000	6.70168	6.74787	17.92289	18.88247	30.94890	1.14215	-0.08621

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TABLE 3

1/A = 0.00201   1/B = 0.   THETA = 1.10

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-3.72517	-3.68070	-2.40762	8.49701	15.71501	0.98974	-5.49888
-4.800	-3.32716	-3.29821	-1.61161	8.89502	16.31102	1.00684	-5.32731
-4.600	-2.93017	-2.91131	-0.81763	9.29201	16.90499	1.01829	-5.15431
-4.400	-2.53461	-2.52224	-0.02650	9.68757	17.49612	1.02581	-4.98412
-4.200	-2.14093	-2.13271	0.76086	10.08125	18.08349	1.03068	-4.82084
-4.000	-1.74953	-1.74397	1.54365	10.47265	18.66627	1.03382	-4.66813
-3.800	-1.36069	-1.35681	2.32133	10.86149	19.24396	1.03584	-4.52844
-3.600	-0.97450	-0.97170	3.09371	11.24768	19.81633	1.03714	-4.40206
-3.400	-0.59111	-0.58900	3.86049	11.63107	20.38311	1.03798	-4.28642
-3.200	-0.21112	-0.20944	4.62047	12.01106	20.94310	1.03852	-4.17634
-3.000	0.16403	0.16543	5.37078	12.38621	21.49341	1.03887	-4.06533
-2.800	0.53190	0.53312	6.10652	12.75408	22.02914	1.03910	-3.94731
-2.600	0.88911	0.89022	6.82094	13.11129	22.54357	1.03925	-3.81797
-2.400	1.23174	1.23277	7.50619	13.45392	23.02882	1.03934	-3.67528
-2.200	1.55604	1.55702	8.15479	13.77822	23.47741	1.03940	-3.51943
-2.000	1.85948	1.86044	8.76168	14.08166	23.88431	1.03944	-3.35220
-1.800	2.14170	2.14265	9.32613	14.36389	24.24875	1.03947	-3.17625
-1.600	2.40472	2.40565	9.85216	14.62690	24.57478	1.03950	-2.99443
-1.400	2.65239	2.65332	10.34750	14.87457	24.87013	1.03952	-2.80949
-1.200	2.88948	2.89042	10.82168	15.11166	25.14430	1.03955	-2.62396
-1.000	3.12086	3.12180	11.28443	15.34304	25.40706	1.03959	-2.44028
-0.800	3.35104	3.35201	11.74480	15.57322	25.66743	1.03966	-2.26085
-0.600	3.58395	3.58496	12.21062	15.80613	25.93325	1.03978	-2.08794
-0.400	3.82260	3.82369	12.68791	16.04478	26.21053	1.03998	-1.92339
-0.200	4.06874	4.06998	13.18021	16.29093	26.50283	1.04033	-1.76814
-0.000	4.32281	4.32430	13.68833	16.54499	26.81095	1.04097	-1.62212
0.200	4.58428	4.58627	14.21128	16.80646	27.13390	1.04217	-1.48460
0.400	4.85258	4.85551	14.74787	17.07476	27.47050	1.04441	-1.35512
0.600	5.12744	5.13217	15.29760	17.34962	27.82023	1.04867	-1.23405
0.800	5.40826	5.41645	15.85923	17.63044	28.18186	1.05683	-1.12220
1.000	5.69241	5.70724	16.42754	17.91459	28.55016	1.07229	-1.01963
1.200	5.97399	6.00117	16.99069	18.19617	28.91331	1.10041	-0.92473
1.400	6.24446	6.29315	17.53163	18.46664	29.25426	1.14750	-0.83418
1.600	6.49599	6.57882	18.03470	18.71817	29.55732	1.21763	-0.74391
1.800	6.72502	6.85685	18.49276	18.94720	29.81539	1.30909	-0.65042
2.000	6.93297	7.12921	18.90866	19.15515	30.03129	1.41466	-0.55183

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TABLE 4

1/A = 0.00201		1/B = 0.		THETA = 1.20			
LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-2.33474	-2.33213	0.89192	9.92523	17.11747	1.03735	-5.73696
-4.800	-1.95727	-1.95526	1.64686	10.30270	17.67242	1.03810	-5.61104
-4.600	-1.58381	-1.58220	2.39378	10.67616	18.21933	1.03858	-5.49549
-4.400	-1.21517	-1.21381	3.13105	11.04480	18.75661	1.03891	-5.38481
-4.200	-0.85331	-0.85211	3.85478	11.40666	19.28033	1.03912	-5.27248
-4.000	-0.50132	-0.50023	4.55875	11.75865	19.78430	1.03925	-5.15266
-3.800	-0.16300	-0.16197	5.23540	12.09697	20.26095	1.03934	-5.02140
-3.600	0.15796	0.15894	5.87732	12.41793	20.70287	1.03940	-4.87701
-3.400	0.45887	0.45983	6.47914	12.71884	21.10469	1.03944	-4.71973
-3.200	0.73895	0.73989	7.03929	12.99892	21.46485	1.03946	-4.55123
-3.000	0.99961	1.00053	7.56061	13.25958	21.78616	1.03948	-4.37390
-2.800	1.24400	1.24492	8.04939	13.50397	22.07495	1.03949	-4.19027
-2.600	1.47613	1.47705	8.51366	13.73610	22.33921	1.03950	-4.00272
-2.400	1.70005	1.70096	8.96149	13.96002	22.58705	1.03951	-3.81334
-2.200	1.91945	1.92036	9.40029	14.17942	22.82584	1.03952	-3.62405
-2.000	2.13761	2.13852	9.83661	14.39758	23.06216	1.03954	-3.43675
-1.800	2.35749	2.35841	10.27637	14.61746	23.30192	1.03956	-3.25340
-1.600	2.58179	2.58272	10.72497	14.84176	23.55052	1.03959	-3.07602
-1.400	2.81278	2.81374	11.18696	15.07275	23.81252	1.03965	-2.90643
-1.200	3.05197	3.05297	11.66534	15.31194	24.09089	1.03976	-2.74581
-1.000	3.29973	3.30080	12.16085	15.55970	24.38640	1.03994	-2.59431
-0.800	3.55544	3.55665	12.67228	15.81541	24.69784	1.04028	-2.45117
-0.600	3.81828	3.81974	13.19795	16.07825	25.02351	1.04091	-2.31552
-0.400	4.08799	4.08994	13.73737	16.34796	25.36292	1.04209	-2.18722
-0.200	4.36496	4.36786	14.29132	16.62493	25.71687	1.04434	-2.06708
-0.000	4.64921	4.65396	14.85982	16.90918	26.08537	1.04874	-1.95593
0.200	4.93868	4.94706	15.43876	17.19865	26.46431	1.05729	-1.85333
0.400	5.22811	5.24347	16.01762	17.48808	26.84317	1.07353	-1.75693
0.600	5.50938	5.53753	16.58015	17.76935	27.20570	1.10259	-1.66284
0.800	5.77379	5.82355	17.10897	18.03376	27.53452	1.14980	-1.56692
1.000	6.01546	6.09835	17.59231	18.27543	27.81786	1.21775	-1.46601
1.200	6.23339	6.36245	18.02818	18.49336	28.05374	1.30420	-1.35864
1.400	6.43082	6.61947	18.42303	18.69079	28.24858	1.40303	-1.24540
1.600	6.61312	6.87480	18.78764	18.87309	28.41320	1.50703	-1.12884
1.800	6.78616	7.13454	19.13371	19.04613	28.55926	1.60982	-1.01298
2.000	6.95530	7.40482	19.47199	19.21526	28.69754	1.70647	-0.90241

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TABLE 5

1/A = 0.00201   1/B = 0.   THETA = 1.30

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-1.25509	-1.25411	3.56599	11.03965	17.89989	1.03940	-6.22230
-4.800	-0.95462	-0.95367	4.16692	11.34011	18.30083	1.03943	-6.07679
-4.600	-0.67364	-0.67270	4.72888	11.62109	18.66279	1.03946	-5.91876
-4.400	-0.41150	-0.41058	5.25315	11.88323	18.98706	1.03948	-5.74974
-4.200	-0.16588	-0.16497	5.74439	12.12885	19.27830	1.03949	-5.57190
-4.000	0.06655	0.06746	6.20926	12.36128	19.54316	1.03949	-5.38752
-3.800	0.28932	0.29023	6.65479	12.58405	19.78870	1.03950	-5.19873
-3.600	0.50563	0.50654	7.08742	12.80036	20.02133	1.03950	-5.00735
-3.400	0.71820	0.71910	7.51255	13.01293	20.24646	1.03951	-4.81494
-3.200	0.92930	0.93021	7.93477	13.22404	20.46867	1.03951	-4.62294
-3.000	1.14100	1.14191	8.35816	13.43573	20.69206	1.03952	-4.43281
-2.800	1.35527	1.35618	8.78670	13.65000	20.92061	1.03952	-4.24616
-2.600	1.57414	1.57506	9.22445	13.86888	21.15836	1.03954	-4.06478
-2.400	1.79955	1.80047	9.67527	14.09429	21.40917	1.03956	-3.89047
-2.200	2.03301	2.03393	10.14217	14.32774	21.67608	1.03959	-3.72461
-2.000	2.27512	2.27607	10.62640	14.56985	21.96031	1.03965	-3.56772
-1.800	2.52545	2.52643	11.12706	14.82018	22.26097	1.03974	-3.41925
-1.600	2.78294	2.78399	11.64204	15.07767	22.57595	1.03992	-3.27807
-1.400	3.04689	3.04807	12.16993	15.34162	22.90384	1.04024	-3.14345
-1.200	3.31758	3.31901	12.71132	15.61231	23.24523	1.04085	-3.01578
-1.000	3.59595	3.59787	13.26805	15.89068	23.60196	1.04202	-2.89618
-0.800	3.88224	3.88512	13.84064	16.17697	23.97455	1.04432	-2.78537
-0.600	4.17456	4.17936	14.42529	16.46930	24.35919	1.04886	-2.68234
-0.400	4.46814	4.47668	15.01244	16.76287	24.74634	1.05768	-2.58398
-0.200	4.75586	4.77148	15.58789	17.05060	25.12180	1.07413	-2.48597
-0.000	5.02992	5.05810	16.13599	17.32465	25.46990	1.10267	-2.38426
0.200	5.28390	5.33263	16.64397	17.57864	25.77788	1.14759	-2.27618
0.400	5.51477	5.59417	17.10570	17.80950	26.03961	1.21084	-2.16083
0.600	5.72341	5.84500	17.52299	18.01815	26.25690	1.29083	-2.03899
0.800	5.91370	6.03968	17.90356	18.20843	26.43747	1.38314	-1.91287
1.000	6.09079	6.33386	18.25775	18.38553	26.59165	1.48218	-1.78588
1.200	6.25986	6.58336	18.59589	18.55460	26.72980	1.58239	-1.66202
1.400	6.42548	6.84358	18.92711	18.72021	26.86102	1.67882	-1.54532
1.600	6.59149	7.11931	19.25913	18.88622	26.99304	1.76727	-1.43951
1.800	6.76104	7.41456	19.59825	19.05578	27.13215	1.84460	-1.34759
2.000	6.93648	7.73208	19.94912	19.23121	27.28303	1.90889	-1.27119

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TABLE 6

1/A = 0.00201   1/B = 0.   THETA = 1.40

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-0.90357	-0.90266	4.78033	11.42334	17.22733	1.03950	-6.39610
-4.800	-0.69142	-0.69051	5.20463	11.63550	17.45163	1.03950	-6.20386
-4.600	-0.48254	-0.48164	5.62239	11.84437	17.66939	1.03950	-6.00991
-4.400	-0.27529	-0.27438	6.03690	12.05163	17.88390	1.03951	-5.81540
-4.200	-0.06825	-0.06734	6.45098	12.25867	18.09797	1.03951	-5.62139
-4.000	0.13991	0.14082	6.86730	12.46683	18.31430	1.03951	-5.42903
-3.800	0.35064	0.35154	7.28875	12.67755	18.53574	1.03951	-5.23962
-3.600	0.56553	0.56644	7.71854	12.89245	18.76554	1.03952	-5.05472
-3.400	0.78633	0.78724	8.16015	13.11325	19.00714	1.03953	-4.87602
-3.200	1.01462	1.01553	8.61672	13.34154	19.26372	1.03954	-4.70510
-3.000	1.25136	1.25227	9.09019	13.57827	19.53719	1.03956	-4.54286
-2.800	1.49645	1.49737	9.58038	13.82337	19.82738	1.03959	-4.38914
-2.600	1.74889	1.74983	10.08526	14.07581	20.13226	1.03964	-4.24285
-2.400	2.00752	2.00849	10.60252	14.33444	20.44952	1.03973	-4.10278
-2.200	2.27202	2.27305	11.13151	14.59893	20.77851	1.03990	-3.96858
-2.000	2.54322	2.54438	11.67391	14.87013	21.12091	1.04021	-3.84114
-1.800	2.82238	2.82379	12.23224	15.14930	21.47924	1.04081	-3.72184
-1.600	3.10974	3.11164	12.80696	15.43666	21.85395	1.04199	-3.61113
-1.400	3.40320	3.40608	13.39388	15.73012	22.24088	1.04433	-3.50737
-1.200	3.69813	3.70294	13.98373	16.02504	22.63073	1.04892	-3.40681
-1.000	3.98827	3.99680	14.56401	16.31518	23.01101	1.05765	-3.30478
-0.800	4.26727	4.28258	15.12202	16.59419	23.36902	1.07341	-3.19735
-0.600	4.52991	4.55685	15.64729	16.85682	23.69429	1.09988	-3.08244
-0.400	4.77279	4.81828	16.13305	17.09970	23.98005	1.14067	-2.95979
-0.200	4.99487	5.06778	16.57721	17.32178	24.22421	1.19784	-2.83053
-0.000	5.19761	5.30832	16.98269	17.52452	24.42969	1.27095	-2.69666
0.200	5.38441	5.54438	17.35630	17.71133	24.60330	1.35716	-2.56096
0.400	5.55960	5.78117	17.70668	17.88652	24.75367	1.45210	-2.42666
0.600	5.72745	6.02383	18.04237	18.05436	24.88937	1.55066	-2.29714
0.800	5.89184	6.27711	18.37116	18.21876	25.01816	1.64770	-2.17574
1.000	6.05623	6.54539	18.69994	18.38315	25.14694	1.73861	-2.06577
1.200	6.22352	6.83234	19.03452	18.55044	25.28152	1.81963	-1.97013
1.400	6.39577	7.14027	19.37901	18.72268	25.42601	1.88815	-1.89047
1.600	6.57399	7.46950	19.73546	18.90091	25.58245	1.94302	-1.82652
1.800	6.75841	7.81874	20.10429	19.08532	25.75128	1.98470	-1.77625
2.000	6.94902	8.18630	20.48551	19.27593	25.93251	2.01492	-1.73676

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TABLE 7

1/A = 0.00201   1/B = 0.   THETA = 1.50

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-0.86241	-0.86150	5.37091	11.49447	15.93518	1.03951	-6.42567
-4.800	-0.65422	-0.65331	5.78729	11.70266	16.15156	1.03951	-6.23397
-4.600	-0.44247	-0.44157	6.21078	11.91441	16.37505	1.03951	-6.04602
-4.400	-0.22563	-0.22473	6.64446	12.13125	16.60873	1.03952	-5.86338
-4.200	-0.00209	-0.00119	7.09155	12.35479	16.85582	1.03952	-5.68766
-4.000	0.22942	0.23032	7.55455	12.58630	17.11882	1.03953	-5.52012
-3.800	0.46928	0.47018	8.03428	12.82616	17.39855	1.03954	-5.36112
-3.600	0.71681	0.71772	8.52934	13.07369	17.69361	1.03956	-5.20988
-3.400	0.97064	0.97155	9.03700	13.32752	18.00127	1.03959	-5.06496
-3.200	1.22975	1.23068	9.55522	13.58663	18.31949	1.03964	-4.92530
-3.000	1.49433	1.49529	10.08438	13.85121	18.64865	1.03973	-4.79107
-2.800	1.76570	1.76672	10.62712	14.12258	18.99139	1.03989	-4.66363
-2.600	2.04529	2.04644	11.18630	14.40217	19.35057	1.04019	-4.54447
-2.400	2.33310	2.33450	11.76193	14.68998	19.72620	1.04079	-4.43368
-2.200	2.62668	2.62857	12.34908	14.98356	20.11335	1.04197	-4.32903
-2.000	2.92125	2.92412	12.93823	15.27813	20.50250	1.04429	-4.22618
-1.800	3.21107	3.21580	13.51785	15.56794	20.88212	1.04874	-4.12021
-1.600	3.49100	3.49920	14.07773	15.84788	21.24200	1.05689	-4.00734
-1.400	3.75748	3.77179	14.61069	16.11436	21.57496	1.07112	-3.88600
-1.200	4.00833	4.03286	15.11239	16.36521	21.87666	1.09447	-3.75662
-1.000	4.24228	4.28294	15.58028	16.59916	22.14455	1.13022	-3.62077
-0.800	4.45896	4.52354	16.01364	16.81584	22.37791	1.18086	-3.48047
-0.600	4.65933	4.75734	16.41439	17.01621	22.57866	1.24708	-3.33796
-0.400	4.84576	4.98809	16.78725	17.20264	22.75152	1.32741	-3.19576
-0.200	5.02145	5.22015	17.13863	17.37833	22.90290	1.41841	-3.05649
-0.000	5.18984	5.45795	17.47540	17.54672	23.03967	1.51539	-2.92276
0.200	5.35435	5.70582	17.80441	17.71122	23.16868	1.61313	-2.79739
0.400	5.51829	5.96808	18.13230	17.87517	23.29657	1.70670	-2.68354
0.600	5.68460	6.24854	18.46492	18.04148	23.42919	1.79182	-2.58420
0.800	5.85532	6.54955	18.80636	18.21220	23.57063	1.86522	-2.50120
1.000	6.03133	6.87122	19.15839	18.38821	23.72266	1.92499	-2.43431
1.200	6.21251	7.21157	19.52075	18.56939	23.88502	1.97102	-2.38139
1.400	6.39827	7.56764	19.89226	18.75515	24.05653	2.00475	-2.33931
1.600	6.58822	7.93696	20.27216	18.94510	24.23642	2.02852	-2.30518
1.800	6.78266	8.31875	20.66104	19.13954	24.42531	2.04481	-2.27709
2.000	6.98280	8.71433	21.06132	19.33968	24.62559	2.05575	-2.25415

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TABLE 8

1/A = 0.00201   1/B = 0.   THETA = 1.60

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-0.79022	-0.78932	6.02077	11.59469	14.70605	1.03952	-6.49984
-4.800	-0.55561	-0.55471	6.48999	11.82930	14.97526	1.03953	-6.33549
-4.600	-0.31306	-0.31216	6.97509	12.07185	15.26036	1.03954	-6.17922
-4.400	-0.06377	-0.06287	7.47367	12.32114	15.55894	1.03955	-6.02973
-4.200	0.19075	0.19165	7.98271	12.57566	15.86798	1.03957	-5.88546
-4.000	0.44982	0.45073	8.50085	12.83473	16.18612	1.03959	-5.74569
-3.800	0.71416	0.71509	9.02953	13.09907	16.51480	1.03964	-5.61113
-3.600	0.98550	0.98645	9.57220	13.37041	16.85748	1.03972	-5.48355
-3.400	1.26528	1.26630	10.13177	13.65019	17.21705	1.03987	-5.36441
-3.200	1.55320	1.55434	10.70761	13.93811	17.59288	1.04017	-5.25344
-3.000	1.84634	1.84772	11.29388	14.23125	17.97915	1.04076	-5.14781
-2.800	2.13968	2.14154	11.88056	14.52458	18.36583	1.04192	-5.04272
-2.600	2.42768	2.43047	12.45656	14.81259	18.74183	1.04412	-4.93303
-2.400	2.70604	2.71054	13.01328	15.09094	19.09855	1.04818	-4.81512
-2.200	2.97251	2.98005	13.54622	15.35741	19.43149	1.05536	-4.68785
-2.000	3.22648	3.23925	14.05417	15.61139	19.73944	1.06756	-4.55224
-1.800	3.46783	3.48924	14.53687	15.85274	20.02215	1.08739	-4.41036
-1.600	3.69611	3.73117	14.99342	16.08101	20.27869	1.11796	-4.26443
-1.400	3.91068	3.96626	15.42257	16.29559	20.50784	1.16211	-4.11642
-1.200	4.11157	4.19637	15.82434	16.49648	20.70961	1.22152	-3.96823
-1.000	4.29989	4.42425	16.20098	16.68480	20.88626	1.29584	-3.82179
-0.800	4.47772	4.65333	16.55665	16.86263	21.04193	1.38256	-3.67899
-0.600	4.64778	4.88739	16.89677	17.03269	21.18204	1.47743	-3.54181
-0.400	4.81321	5.13057	17.22763	17.19812	21.31291	1.57539	-3.41277
-0.200	4.97739	5.38738	17.55599	17.36230	21.44126	1.67135	-3.29505
-0.000	5.14340	5.66198	17.88800	17.52831	21.57328	1.76065	-3.19192
0.200	5.31342	5.95705	18.22804	17.69832	21.71331	1.83930	-3.10543
0.400	5.48834	6.27282	18.57788	17.87325	21.86316	1.90458	-3.03547
0.600	5.66792	6.60708	18.93705	18.05283	22.02232	1.95564	-2.97983
0.800	5.85131	6.95625	19.30382	18.23621	22.18909	1.99352	-2.93515
1.000	6.03767	7.31688	19.67654	18.42258	22.36182	2.02045	-2.89821
1.200	6.22673	7.68685	20.05466	18.61164	22.53994	2.03903	-2.86688
1.400	6.41892	8.06581	20.43905	18.80383	22.72432	2.05160	-2.84029
1.600	6.61530	8.45498	20.83180	19.00021	22.91708	2.05999	-2.81840
1.800	6.81737	8.85678	21.23595	19.20228	23.12123	2.06552	-2.80124
2.000	7.02721	9.27492	21.65562	19.41212	23.34089	2.06913	-2.78849

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TABLE 9

1/A = 0.00201   1/B = 0.   THETA = 1.70

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-0.59077	-0.58988	6.92263	11.82046	13.73227	1.03955	-6.70430
-4.800	-0.33213	-0.33123	7.43992	12.07911	14.04956	1.03957	-6.56403
-4.600	-0.06822	-0.06732	7.96773	12.34301	14.37737	1.03960	-6.42897
-4.400	0.20296	0.20388	8.51010	12.61420	14.71973	1.03964	-6.30116
-4.200	0.48280	0.48375	9.06976	12.89404	15.07942	1.03972	-6.18198
-4.000	0.77062	0.77162	9.64541	13.18185	15.45505	1.03987	-6.07075
-3.800	1.06304	1.06417	10.23026	13.47428	15.83989	1.04016	-5.96412
-3.600	1.35477	1.35613	10.81571	13.76600	16.22335	1.04073	-5.85689
-3.400	1.64034	1.64215	11.38486	14.05158	16.59449	1.04180	-5.74380
-3.200	1.91593	1.91857	11.93604	14.32717	16.94568	1.04377	-5.62135
-3.000	2.18016	2.18427	12.46450	14.59140	17.27414	1.04726	-5.48874
-2.800	2.43362	2.44028	12.97141	14.84485	17.58104	1.05328	-5.34741
-2.600	2.67753	2.68850	13.45924	15.08877	17.86887	1.06337	-5.19991
-2.400	2.91254	2.93061	13.92925	15.32377	18.13888	1.07978	-5.04878
-2.200	3.13813	3.16754	14.38043	15.54936	18.39007	1.10542	-4.89599
-2.000	3.35311	3.39986	14.81040	15.76435	18.62003	1.14337	-4.74305
-1.800	3.55650	3.62850	15.21718	15.96774	18.82682	1.19600	-4.59131
-1.600	3.74822	3.85518	15.60061	16.15945	19.01025	1.26399	-4.44205
-1.400	3.92927	4.08238	15.96272	16.34051	19.17235	1.34574	-4.29651
-1.200	4.10176	4.31336	16.30769	16.51299	19.31732	1.43764	-4.15619
-1.000	4.26869	4.55224	16.64155	16.67992	19.45119	1.53495	-4.02351
-0.800	4.43358	4.80383	16.97133	16.84481	19.58097	1.63267	-3.90186
-0.600	4.59973	5.07274	17.30363	17.01096	19.71327	1.72588	-3.79479
-0.400	4.76950	5.36212	17.64318	17.18074	19.85281	1.80992	-3.70464
-0.200	4.94389	5.67248	17.99196	17.35513	20.00160	1.88118	-3.63146
-0.000	5.12265	6.00167	18.34948	17.53389	20.15912	1.93792	-3.57303
0.200	5.30479	6.34579	18.71376	17.71603	20.32340	1.98059	-3.52577
0.400	5.48925	6.70077	19.08267	17.90048	20.49231	2.01125	-3.48611
0.600	5.67541	7.06368	19.45500	18.08665	20.66464	2.03256	-3.45155
0.800	5.86339	7.43333	19.83095	18.27462	20.84059	2.04707	-3.42111
1.000	6.05386	7.81009	20.21189	18.46509	21.02153	2.05681	-3.39498
1.200	6.24776	8.19514	20.59970	18.65900	21.20933	2.06329	-3.37366
1.400	6.44609	8.59001	20.99637	18.85733	21.40600	2.06755	-3.35726
1.600	6.65000	8.99665	21.40418	19.06124	21.61382	2.07033	-3.34531
1.800	6.86116	9.41821	21.82650	19.27240	21.83613	2.07212	-3.33698
2.000	7.08232	9.86006	22.26882	19.49356	22.07846	2.07327	-3.33136

TABLE 10

1/A = 0.00201   1/B = 0.   THETA = 1.80

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	-0.30184	-0.30093	8.00117	12.13422	12.93822	1.03964	-6.99743
-4.800	-0.01424	-0.01330	8.57637	12.42182	13.31342	1.03971	-6.88589
-4.600	0.27735	0.27835	9.15956	12.71341	13.69661	1.03986	-6.77828
-4.400	0.56738	0.56849	9.73962	13.00344	14.07666	1.04014	-6.66907
-4.200	0.85040	0.85173	10.30565	13.28646	14.44270	1.04066	-6.55293
-4.000	1.12287	1.12460	10.85060	13.55894	14.78765	1.04160	-6.42650
-3.800	1.38394	1.38637	11.37274	13.82000	15.10979	1.04327	-6.28918
-3.600	1.63491	1.63854	11.87467	14.07097	15.41171	1.04614	-6.14271
-3.400	1.87798	1.88367	12.36081	14.31404	15.69785	1.05100	-5.98998
-3.200	2.11497	2.12413	12.83480	14.55103	15.97184	1.05914	-5.83389
-3.000	2.34644	2.36134	13.29774	14.78250	16.23478	1.07248	-5.67663
-2.800	2.57153	2.59571	13.74792	15.00760	16.48497	1.09366	-5.51957
-2.600	2.78853	2.82715	14.18191	15.22459	16.71895	1.12579	-5.36367
-2.400	2.99560	3.05578	14.59606	15.43166	16.93311	1.17173	-5.20974
-2.200	3.19160	3.28229	14.98805	15.62766	17.12509	1.23302	-5.05845
-2.000	3.37655	3.50831	15.35795	15.81261	17.29500	1.30900	-4.91050
-1.800	3.55201	3.73668	15.70888	15.98807	17.44593	1.39685	-4.76712
-1.600	3.72092	3.97155	16.04670	16.15698	17.58374	1.49241	-4.63077
-1.400	3.88694	4.21807	16.37874	16.32300	17.71579	1.59098	-4.50508
-1.200	4.05361	4.48134	16.71207	16.48967	17.84912	1.68751	-4.39393
-1.000	4.22347	4.76498	17.05179	16.65953	17.98884	1.77682	-4.29994
-0.800	4.39767	5.06996	17.40020	16.83373	18.13725	1.85435	-4.22338
-0.600	4.57602	5.39432	17.75690	17.01208	18.29395	1.91735	-4.16207
-0.400	4.75749	5.73406	18.11983	17.19355	18.45688	1.96550	-4.11227
-0.200	4.94084	6.08464	18.48653	17.37690	18.62357	2.00049	-4.07003
-0.000	5.12523	6.44249	18.85532	17.56129	18.79237	2.02503	-4.03239
0.200	5.31056	6.80580	19.22598	17.74662	18.96303	2.04183	-3.99808
0.400	5.49739	7.17457	19.59964	17.93345	19.13669	2.05318	-3.96738
0.600	5.68661	7.54976	19.97808	18.12267	19.31512	2.06078	-3.94125
0.800	5.87900	7.93241	20.36286	18.31506	19.49991	2.06582	-3.92037
1.000	6.07512	8.32325	20.75510	18.51119	19.69215	2.06914	-3.90470
1.200	6.27546	8.72301	21.15577	18.71152	19.89282	2.07130	-3.89352
1.400	6.48078	9.13307	21.56642	18.91684	20.10346	2.07269	-3.88585
1.600	6.69256	9.55626	21.98998	19.12862	20.32703	2.07358	-3.88074
1.800	6.91343	9.99775	22.43171	19.34949	20.56876	2.07414	-3.87739
2.000	7.14765	10.46605	22.90016	19.58371	20.83721	2.07450	-3.87523

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TABLE 11

1/A = 0.00201   1/B = 0.   THETA = 1.90

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	0.05864	0.05973	9.22069	12.51818	12.28794	1.04010	-7.36074
-4.800	0.32809	0.32938	9.75960	12.78763	12.62685	1.04055	-7.23085
-4.600	0.58586	0.58747	10.27514	13.04540	12.94238	1.04133	-7.08948
-4.400	0.83361	0.83579	10.77064	13.29315	13.23788	1.04268	-6.93851
-4.200	1.07410	1.07724	11.25161	13.53364	13.51885	1.04497	-6.78102
-4.000	1.30994	1.31471	11.72331	13.76949	13.79055	1.04882	-6.62020
-3.800	1.54277	1.55029	12.18897	14.00232	14.05621	1.05528	-6.45852
-3.600	1.77276	1.78484	12.64893	14.23230	14.31618	1.06597	-6.29754
-3.400	1.99871	2.01828	13.10084	14.45825	14.56808	1.08322	-6.13802
-3.200	2.21854	2.25001	13.54050	14.67808	14.80775	1.11002	-5.98044
-3.000	2.42983	2.47943	13.96309	14.88938	15.03033	1.14947	-5.82510
-2.800	2.63051	2.70638	14.36445	15.09006	15.23169	1.20378	-5.67216
-2.600	2.81976	2.93170	14.74295	15.27931	15.41019	1.27323	-5.52189
-2.400	2.99864	3.15786	15.10070	15.45818	15.56794	1.35592	-5.37543
-2.200	3.16997	3.38904	15.44336	15.62951	15.71060	1.44850	-5.23535
-2.000	3.33755	3.63070	15.77853	15.79710	15.84577	1.54674	-5.10555
-1.800	3.50510	3.88836	16.11362	15.96464	15.98087	1.64573	-4.99019
-1.600	3.67536	4.16617	16.45414	16.13490	16.12139	1.73989	-4.89218
-1.400	3.84965	4.46560	16.80271	16.30919	16.26995	1.82379	-4.81206
-1.200	4.02787	4.78504	17.15916	16.48741	16.42640	1.89352	-4.74776
-1.000	4.20900	5.12055	17.52143	16.66855	16.58867	1.94781	-4.69545
-0.800	4.39171	5.46724	17.88684	16.85125	16.75408	1.98781	-4.65080
-0.600	4.57494	5.82093	18.25330	17.03448	16.92055	2.01611	-4.61034
-0.400	4.75838	6.17921	18.62017	17.21792	17.08742	2.03563	-4.57235
-0.200	4.94250	6.54171	18.98842	17.40204	17.25566	2.04889	-4.53697
-0.000	5.12829	6.90946	19.35999	17.58783	17.42724	2.05783	-4.50551
0.200	5.31669	7.28373	19.73681	17.77624	17.60405	2.06381	-4.47935
0.400	5.50828	7.66523	20.11998	17.96782	17.78723	2.06777	-4.45901
0.600	5.70322	8.05400	20.50985	18.16276	17.97709	2.07037	-4.44411
0.800	5.90152	8.44989	20.90645	18.36106	18.17369	2.07206	-4.43369
1.000	6.10338	8.85316	21.31018	18.56292	18.37742	2.07315	-4.42665
1.200	6.30947	9.26505	21.72237	18.76902	18.58961	2.07385	-4.42201
1.400	6.52121	9.68834	22.14585	18.98076	18.81309	2.07429	-4.41899
1.600	6.74112	10.12804	22.58566	19.20066	19.05291	2.07457	-4.41705
1.800	6.97328	10.59228	23.04998	19.43282	19.31722	2.07475	-4.41581
2.000	7.22374	11.09317	23.55090	19.68328	19.61815	2.07486	-4.41502

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TABLE 12

1/A = 0.00201   1/B = 0.   THETA = 2.00

LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	0.26880	0.27073	10.13762	12.75061	11.33762	1.04210	-7.57330
-4.800	0.50197	0.50465	10.60396	12.98378	11.60395	1.04389	-7.40805
-4.600	0.73333	0.73728	11.06668	13.21514	11.86667	1.04690	-7.24202
-4.400	0.96402	0.97012	11.52807	13.44584	12.12806	1.05197	-7.07703
-4.200	1.19382	1.20354	11.98768	13.67564	12.38767	1.06043	-6.91400
-4.000	1.42134	1.43703	12.44270	13.90316	12.64270	1.07431	-6.75321
-3.800	1.64429	1.66964	12.88860	14.12611	12.88860	1.09633	-6.59471
-3.600	1.85984	1.90024	13.31971	14.34166	13.11971	1.12964	-6.43836
-3.400	2.06525	2.12791	13.73054	14.54707	13.33053	1.17688	-6.28389
-3.200	2.25898	2.35286	14.11798	14.74080	13.51798	1.23918	-6.13130
-3.000	2.44160	2.57718	14.48324	14.92342	13.68323	1.31570	-5.98170
-2.800	2.61580	2.80507	14.83163	15.09762	13.83163	1.40400	-5.83785
-2.600	2.78540	3.04217	15.17083	15.26722	13.97083	1.50058	-5.70389
-2.400	2.95424	3.29435	15.50851	15.43606	14.10850	1.60088	-5.58422
-2.200	3.12523	3.56624	15.85048	15.60705	14.25048	1.69918	-5.48203
-2.000	3.29986	3.85990	16.19974	15.78168	14.39974	1.78927	-5.39816
-1.800	3.47819	4.17421	16.55641	15.96001	14.55641	1.86608	-5.33074
-1.600	3.65926	4.50539	16.91855	16.14108	14.71855	1.92714	-5.27589
-1.400	3.84166	4.84838	17.28334	16.32348	14.88334	1.97284	-5.22901
-1.200	4.02415	5.19841	17.64832	16.50597	15.04832	2.00554	-5.18608
-1.000	4.20617	5.55236	18.01237	16.68799	15.21237	2.02825	-5.14476
-0.800	4.38807	5.90939	18.37616	16.86989	15.37616	2.04376	-5.10484
-0.600	4.57089	6.27051	18.74181	17.05271	15.54181	2.05428	-5.06780
-0.400	4.75588	6.63747	19.11179	17.23770	15.71178	2.06137	-5.03562
-0.200	4.94389	7.01147	19.48780	17.42571	15.88780	2.06612	-5.00965
-0.000	5.13518	7.39272	19.87039	17.61700	16.07038	2.06926	-4.99003
0.200	5.32959	7.78068	20.25921	17.81141	16.25921	2.07133	-4.97600
0.400	5.52683	8.17460	20.65369	18.00865	16.45369	2.07266	-4.96636
0.600	5.72674	8.57405	21.05351	18.20856	16.65351	2.07352	-4.95992
0.800	5.92950	8.97935	21.45903	18.41132	16.85903	2.07407	-4.95571
1.000	6.13580	9.39179	21.87162	18.61761	17.07162	2.07442	-4.95299
1.200	6.34701	9.81411	22.29404	18.82882	17.29404	2.07464	-4.95125
1.400	6.56552	10.25108	22.73107	19.04734	17.53106	2.07478	-4.95014
1.600	6.79516	10.71032	23.19034	19.27698	17.79034	2.07487	-4.94944
1.800	7.04163	11.20325	23.68329	19.52345	18.08329	2.07493	-4.94899
2.000	7.31250	11.74498	24.22504	19.79432	18.42503	2.07496	-4.94871

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TABLE 13

$LOG_{10}\ P$ FOR $B = 16/1$

LOG PE	1.0	1.1	1.2	1.3	1.4	Θ 1.5	1.6	1.7	1.8	1.9	2.0
-5.00	-4.55935	-3.65564	-2.30591	-1.22783	-0.87639	-0.83523	-0.76304	-0.56360	-0.27465	0.08602	0.29707
-4.80	-4.29963	-3.27274	-1.92902	-0.92739	-0.66424	-0.62704	-0.52843	-0.30495	0.01298	0.35568	0.53103
-4.60	-4.01918	-2.88556	-1.55595	-0.64643	-0.45536	-0.41529	-0.28588	-0.04104	0.30464	0.61379	0.76374
-4.40	-3.71612	-2.49630	-1.18755	-0.38430	-0.24811	-0.19845	-0.03659	0.23016	0.59479	0.86214	0.99670
-4.20	-3.39083	-2.10665	-0.82585	-0.13869	-0.04107	0.02509	0.21793	0.51003	0.87803	1.10365	1.23032
-4.00	-3.04578	-1.71783	-0.47396	0.09374	0.16709	0.25659	0.47701	0.79791	1.15093	1.34122	1.46416
-3.80	-2.68476	-1.33063	-0.13572	0.31650	0.37782	0.49646	0.74136	1.09046	1.41274	1.57695	1.69731
-3.60	-2.31187	-0.94548	0.18522	0.53281	0.59271	0.74399	1.01273	1.38244	1.66498	1.81177	1.92872
-3.40	-1.93079	-0.56276	0.48610	0.74538	0.81352	0.99783	1.29258	1.66849	1.91023	2.04563	2.15754
-3.20	-1.54451	-0.18319	0.76616	0.95649	1.04181	1.25696	1.58063	1.94495	2.15089	2.27802	2.38400
-3.00	-1.15533	0.19169	1.02681	1.16818	1.27854	1.52157	1.87403	2.21074	2.38842	2.50840	2.61018
-2.80	-0.76489	0.55939	1.27119	1.38246	1.52365	1.79301	2.16788	2.46689	2.62331	2.73667	2.84020
-2.60	-0.37432	0.91649	1.50332	1.60133	1.77611	2.07273	2.45686	2.71536	2.85554	2.96367	3.07961
-2.40	0.01565	1.25904	1.72724	1.82675	2.03477	2.36080	2.73702	2.95787	3.08528	3.19182	3.33418
-2.20	0.40453	1.58330	1.94664	2.06021	2.29934	2.65490	3.00672	3.19543	3.31328	3.42523	3.60840
-2.00	0.79167	1.88672	2.16480	2.30235	2.57067	2.95051	3.26622	3.42867	3.54115	3.66924	3.90419
-1.80	1.17602	2.16892	2.38469	2.55271	2.85010	3.24230	3.51669	3.65860	3.77163	3.92926	4.22030
-1.60	1.55578	2.43193	2.60900	2.81028	3.13798	3.52590	3.75936	3.88693	4.00880	4.20929	4.55291
-1.40	1.92836	2.67960	2.84002	3.07436	3.43248	3.79884	3.99553	4.11611	4.25767	4.51070	4.89696
-1.20	2.29038	2.91669	3.07925	3.34532	3.72945	4.06049	4.22708	4.34930	4.52323	4.83178	5.24775
-1.00	2.63799	3.14808	3.32708	3.62420	4.02352	4.31144	4.45677	4.59051	4.80898	5.16855	5.60224
-0.80	2.96759	3.37829	3.58294	3.91152	4.30969	4.55327	4.68794	4.84441	5.11578	5.51618	5.95962
-0.60	3.27690	3.61125	3.84605	4.20586	4.58460	4.78868	4.92428	5.11554	5.44161	5.87053	6.32099
-0.40	3.56594	3.84997	4.11628	4.50340	4.84703	5.02137	5.16980	5.40689	5.78247	6.22926	6.68811
-0.20	3.83732	4.09627	4.39426	4.79861	5.09792	5.25563	5.42888	5.71893	6.13387	6.59206	7.06222
-0.00	4.09570	4.35062	4.68046	5.08592	5.34023	5.49574	5.70559	6.04944	6.49229	6.96002	7.44355
0.20	4.34671	4.61262	4.97377	5.36155	5.57838	5.74594	6.00251	6.39455	6.85599	7.33443	7.83156
0.40	4.59580	4.88191	5.27058	5.62463	5.81745	6.01042	6.31981	6.75025	7.22503	7.71602	8.22550
0.60	4.84737	5.15867	5.56535	5.87740	6.06246	6.29288	6.65526	7.11366	7.60039	8.10485	8.62498
0.80	5.10415	5.44315	5.85252	6.12430	6.31805	6.59562	7.00531	7.48365	7.98316	8.50078	9.03028
1.00	5.36726	5.73432	6.12897	6.37086	6.58848	6.91869	7.36658	7.86063	8.37408	8.90407	9.44273
1.20	5.63691	6.02893	6.39517	6.62275	6.87734	7.26011	7.73698	8.24285	8.77389	9.31598	9.86506
1.40	5.91313	6.32206	6.65457	6.88526	7.18687	7.61696	8.11623	8.64079	9.18398	9.73929	10.30204
1.60	6.19595	6.60944	6.91239	7.16308	7.51739	7.98685	8.50559	9.04750	9.60719	10.17899	10.76128
1.80	6.48457	6.88968	7.17458	7.46015	7.86760	8.36901	8.90752	9.46911	10.04869	10.64324	11.25421
2.00	6.77666	7.16459	7.44715	7.77917	8.23586	8.76484	9.32575	9.91098	10.51700	11.14412	11.79593

TABLE 12

| 1/A = 0.00201 | | 1/B = 0. | | THETA = 2.00 | | | |
LOG PE	LOG PH	LOG P	LOG NH2	LOG NH	LOG NHHP	MU	LOG KM
-5.000	0.26880	0.27073	10.13762	12.75061	11.33762	1.04210	-7.57330
-4.800	0.50197	0.50465	10.60396	12.98378	11.60395	1.04389	-7.40805
-4.600	0.73333	0.73728	11.06668	13.21514	11.86667	1.04690	-7.24202
-4.400	0.96402	0.97012	11.52807	13.44584	12.12806	1.05197	-7.07703
-4.200	1.19382	1.20354	11.98768	13.67564	12.38767	1.06043	-6.91400
-4.000	1.42134	1.43703	12.44270	13.90316	12.64270	1.07431	-6.75321
-3.800	1.64429	1.66964	12.88860	14.12611	12.88860	1.09633	-6.59471
-3.600	1.85984	1.90024	13.31971	14.34166	13.11971	1.12964	-6.43836
-3.400	2.06525	2.12791	13.73054	14.54707	13.33053	1.17688	-6.28389
-3.200	2.25898	2.35286	14.11798	14.74080	13.51798	1.23918	-6.13130
-3.000	2.44160	2.57718	14.48324	14.92342	13.68323	1.31570	-5.98170
-2.800	2.61580	2.80507	14.83163	15.09762	13.83163	1.40400	-5.83785
-2.600	2.78540	3.04217	15.17083	15.26722	13.97083	1.50058	-5.70389
-2.400	2.95424	3.29435	15.50851	15.43606	14.10850	1.60088	-5.58422
-2.200	3.12523	3.56624	15.85048	15.60705	14.25048	1.69918	-5.48203
-2.000	3.29986	3.85990	16.19974	15.78168	14.39974	1.78927	-5.39816
-1.800	3.47819	4.17421	16.55641	15.96001	14.55641	1.86608	-5.33074
-1.600	3.65926	4.50539	16.91855	16.14108	14.71855	1.92714	-5.27589
-1.400	3.84166	4.84838	17.28334	16.32348	14.88334	1.97284	-5.22901
-1.200	4.02415	5.19841	17.64832	16.50597	15.04832	2.00554	-5.18608
-1.000	4.20617	5.55236	18.01237	16.68799	15.21237	2.02825	-5.14476
-0.800	4.38807	5.90939	18.37616	16.86989	15.37616	2.04376	-5.10484
-0.600	4.57089	6.27051	18.74181	17.05271	15.54181	2.05428	-5.06780
-0.400	4.75588	6.63747	19.11179	17.23770	15.71178	2.06137	-5.03562
-0.200	4.94389	7.01147	19.48780	17.42571	15.88780	2.06612	-5.00965
-0.000	5.13518	7.39272	19.87039	17.61700	16.07038	2.06926	-4.99003
0.200	5.32959	7.78068	20.25921	17.81141	16.25921	2.07133	-4.97600
0.400	5.52683	8.17460	20.65369	18.00865	16.45369	2.07266	-4.96636
0.600	5.72674	8.57405	21.05351	18.20856	16.65351	2.07352	-4.95992
0.800	5.92950	8.97935	21.45903	18.41132	16.85903	2.07407	-4.95571
1.000	6.13580	9.39179	21.87162	18.61761	17.07162	2.07442	-4.95299
1.200	6.34701	9.81411	22.29404	18.82882	17.29404	2.07464	-4.95125
1.400	6.56552	10.25108	22.73107	19.04734	17.53106	2.07478	-4.95014
1.600	6.79516	10.71032	23.19034	19.27698	17.79034	2.07487	-4.94944
1.800	7.04163	11.20325	23.68329	19.52345	18.08329	2.07493	-4.94899
2.000	7.31250	11.74498	24.22504	19.79432	18.42503	2.07496	-4.94871

TABLE 15

μ FOR B = 16/1

Θ

LOG PE	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
-5.00	0.77361	1.15865	1.21112	1.21337	1.21348	1.21349	1.21350	1.21354	1.21363	1.21414	1.21634
-4.80	0.83013	1.17753	1.21194	1.21341	1.21348	1.21349	1.21351	1.21356	1.21372	1.21463	1.21830
-4.60	0.89497	1.19015	1.21248	1.21344	1.21349	1.21349	1.21352	1.21359	1.21387	1.21550	1.22160
-4.40	0.96227	1.19842	1.21283	1.21345	1.21349	1.21350	1.21354	1.21363	1.21418	1.21698	1.22717
-4.20	1.02525	1.20378	1.21306	1.21347	1.21349	1.21351	1.21355	1.21372	1.21475	1.21949	1.23645
-4.00	1.07872	1.20723	1.21321	1.21347	1.21349	1.21351	1.21358	1.21388	1.21579	1.22372	1.25166
-3.80	1.12050	1.20945	1.21331	1.21348	1.21350	1.21353	1.21363	1.21421	1.21762	1.23081	1.27573
-3.60	1.15106	1.21088	1.21337	1.21348	1.21350	1.21355	1.21372	1.21483	1.22077	1.24252	1.31202
-3.40	1.17238	1.21181	1.21341	1.21349	1.21351	1.21358	1.21389	1.21601	1.22611	1.26140	1.36327
-3.20	1.18674	1.21240	1.21344	1.21349	1.21352	1.21364	1.21422	1.21818	1.23504	1.29066	1.43045
-3.00	1.19622	1.21279	1.21346	1.21350	1.21354	1.21373	1.21487	1.22201	1.24965	1.33358	1.51232
-2.80	1.20238	1.21304	1.21347	1.21351	1.21358	1.21390	1.21614	1.22861	1.27281	1.39234	1.60593
-2.60	1.20635	1.21321	1.21348	1.21352	1.21364	1.21424	1.21856	1.23967	1.30784	1.46696	1.70728
-2.40	1.20891	1.21331	1.21349	1.21354	1.21374	1.21489	1.22301	1.25764	1.35771	1.55507	1.81139
-2.20	1.21055	1.21337	1.21350	1.21358	1.21392	1.21619	1.23089	1.28565	1.42383	1.65276	1.91232
-2.00	1.21161	1.21342	1.21352	1.21364	1.21426	1.21874	1.24426	1.32695	1.50518	1.75533	2.00389
-1.80	1.21229	1.21345	1.21354	1.21375	1.21492	1.22362	1.26597	1.38394	1.59838	1.85757	2.08125
-1.60	1.21272	1.21348	1.21358	1.21394	1.21622	1.23257	1.29931	1.45707	1.69875	1.95381	2.14229
-1.40	1.21300	1.21350	1.21365	1.21430	1.21878	1.24816	1.34729	1.54427	1.80116	2.03873	2.18772
-1.20	1.21318	1.21354	1.21376	1.21497	1.22382	1.27369	1.41145	1.64135	1.90040	2.10873	2.22008
-1.00	1.21330	1.21358	1.21397	1.21625	1.23340	1.31266	1.49114	1.74308	1.99128	2.16286	2.24249
-0.80	1.21339	1.21366	1.21434	1.21878	1.25067	1.36758	1.58328	1.84415	2.06947	2.20255	2.25777
-0.60	1.21345	1.21379	1.21503	1.22376	1.27961	1.43894	1.68308	1.93955	2.13253	2.23052	2.26811
-0.40	1.21353	1.21400	1.21632	1.23343	1.32402	1.52478	1.78503	2.02475	2.18043	2.24976	2.27508
-0.20	1.21362	1.21439	1.21880	1.25146	1.38593	1.62112	1.88386	2.09638	2.21509	2.26282	2.27974
-0.00	1.21377	1.21510	1.22363	1.28265	1.46453	1.72272	1.97489	2.15302	2.23931	2.27160	2.28283
0.20	1.21400	1.21641	1.23301	1.33153	1.55639	1.82403	2.05435	2.19540	2.25587	2.27747	2.28486
0.40	1.21441	1.21888	1.25081	1.39995	1.65653	1.92000	2.11978	2.22572	2.26703	2.28137	2.28617
0.60	1.21514	1.22356	1.28257	1.48579	1.75940	2.00647	2.17065	2.24674	2.27450	2.28392	2.28701
0.80	1.21646	1.23251	1.33394	1.58390	1.85960	2.08038	2.20820	2.26103	2.27946	2.28558	2.28755
1.00	1.21891	1.24945	1.40740	1.68804	1.95251	2.14015	2.23480	2.27060	2.28271	2.28665	2.28789
1.20	1.22347	1.28018	1.50006	1.79229	2.03454	2.18591	2.25312	2.27696	2.28483	2.28733	2.28811
1.40	1.23201	1.33144	1.60491	1.89150	2.10335	2.21930	2.26548	2.28115	2.28619	2.28777	2.28825
1.60	1.24791	1.40726	1.71400	1.98161	2.15810	2.24276	2.27373	2.28388	2.28706	2.28804	2.28833
1.80	1.27671	1.50528	1.82062	2.05968	2.19947	2.25880	2.27916	2.28564	2.28762	2.28821	2.28839
2.00	1.32563	1.61717	1.91977	2.12408	2.22935	2.26956	2.28270	2.28676	2.28797	2.28832	2.28842

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TABLE 16

μ FOR $\beta = 8/1$

LOG PE	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
-5.00	0.89012	1.30963	1.36565	1.36804	1.36817	1.36818	1.36819	1.36823	1.36833	1.36886	1.37121
-4.80	0.95264	1.32982	1.36652	1.36809	1.36817	1.36818	1.36820	1.36825	1.36842	1.36939	1.37330
-4.60	1.02396	1.34329	1.36710	1.36812	1.36817	1.36818	1.36821	1.36828	1.36859	1.37031	1.37682
-4.40	1.09754	1.35212	1.36747	1.36814	1.36817	1.36819	1.36822	1.36833	1.36891	1.37189	1.38273
-4.20	1.16597	1.35783	1.36772	1.36815	1.36817	1.36819	1.36824	1.36842	1.36952	1.37456	1.39261
-4.00	1.22377	1.36151	1.36788	1.36816	1.36818	1.36820	1.36828	1.36860	1.37063	1.37907	1.40875
-3.80	1.26872	1.36388	1.36798	1.36817	1.36818	1.36822	1.36833	1.36894	1.37257	1.38660	1.43427
-3.60	1.30151	1.36540	1.36805	1.36817	1.36819	1.36824	1.36842	1.36960	1.37593	1.39905	1.47264
-3.40	1.32431	1.36638	1.36810	1.36817	1.36820	1.36827	1.36860	1.37086	1.38161	1.41909	1.52661
-3.20	1.33966	1.36702	1.36812	1.36818	1.36821	1.36833	1.36896	1.37316	1.39110	1.45007	1.59696
-3.00	1.34977	1.36743	1.36814	1.36819	1.36823	1.36843	1.36965	1.37724	1.40662	1.49536	1.68212
-2.80	1.35634	1.36770	1.36816	1.36821	1.36827	1.36862	1.37100	1.38427	1.43118	1.55710	1.77874
-2.60	1.36057	1.36787	1.36817	1.36823	1.36833	1.36897	1.37357	1.39602	1.46822	1.63202	1.88243
-2.40	1.36330	1.36798	1.36818	1.36827	1.36844	1.36967	1.37831	1.41510	1.52075	1.72635	1.98798
-2.20	1.36505	1.36805	1.36819	1.36834	1.36864	1.37105	1.38669	1.44477	1.59005	1.82677	2.08937
-2.00	1.36618	1.36810	1.36821	1.36845	1.36900	1.37377	1.40090	1.48838	1.67473	1.93127	2.18057
-1.80	1.36690	1.36814	1.36823	1.36866	1.36970	1.37896	1.42393	1.54830	1.77098	2.03448	2.25705
-1.60	1.36736	1.36816	1.36828	1.36904	1.37108	1.38848	1.45922	1.62472	1.87374	2.13078	2.31703
-1.40	1.36766	1.36819	1.36835	1.36975	1.37381	1.40504	1.50980	1.71520	1.97765	2.21508	2.36146
-1.20	1.36785	1.36823	1.36847	1.37112	1.37918	1.43212	1.57711	1.81509	2.07744	2.28410	2.39300
-1.00	1.36798	1.36828	1.36869	1.37381	1.38937	1.47331	1.66015	1.91884	2.16806	2.33717	2.41480
-0.80	1.36807	1.36836	1.36908	1.37910	1.40771	1.53112	1.75544	2.02099	2.24544	2.37593	2.42963
-0.60	1.36814	1.36849	1.36981	1.38940	1.43838	1.60582	1.85776	2.11656	2.30746	2.40317	2.43966
-0.40	1.36821	1.36872	1.37119	1.40854	1.48529	1.69504	1.96135	2.20124	2.35434	2.42186	2.44641
-0.20	1.36832	1.36914	1.37383	1.44160	1.55038	1.79435	2.06086	2.27194	2.38815	2.43452	2.45093
-0.00	1.36847	1.36989	1.37897	1.49321	1.63248	1.89815	2.15177	2.32754	2.41171	2.44304	2.45392
0.20	1.36872	1.37129	1.38894	1.56507	1.72771	2.00072	2.23051	2.36896	2.42778	2.44873	2.45588
0.40	1.36916	1.37391	1.40785	1.65460	1.83063	2.09704	2.29495	2.39850	2.43861	2.45250	2.45715
0.60	1.36993	1.37889	1.44151	1.75608	1.93539	2.18313	2.34479	2.41893	2.44585	2.45497	2.45796
0.80	1.37134	1.38841	1.49574	1.86283	2.03652	2.25620	2.38143	2.43279	2.45065	2.45658	2.45848
1.00	1.37394	1.40641	1.57286	1.96868	2.12949	2.31493	2.40733	2.44207	2.45380	2.45761	2.45882
1.20	1.37879	1.43898	1.66941	2.06853	2.21093	2.35970	2.42512	2.44824	2.45585	2.45827	2.45903
1.40	1.38788	1.49311	1.77769	2.15844	2.27881	2.39225	2.43711	2.45229	2.45717	2.45869	2.45916
1.60	1.40478	1.57272	1.88928	2.23578	2.33252	2.41506	2.44510	2.45493	2.45801	2.45896	2.45924
1.80	1.43531	1.67483	1.99728	2.29917	2.37293	2.43063	2.45036	2.45663	2.45855	2.45913	2.45929
2.00	1.48699	1.79029	2.09681		2.40202	2.44106	2.45379	2.45772	2.45889	2.45923	2.45933

abundance ratio. Figure 3 exhibits a plot between $\log_{10} P$ and $\log_{10} p_e$, and Figure 4 between μ and $\log_{10} p_e$, for several values of θ.

Figure 5 displays a plot of the ratio of electrons contributed by hydrogen to the electrons contributed by metals as a function of $\log_{10} p_e$ for two values of θ. The interesting feature of this figure is the negative value of the ratio at higher pressures and lower temperatures. This negative value of the ratio implies that, under these conditions, hydrogen is unable to provide enough of its own electrons for the formation of H^-, and so H^- robs metals of some of their electrons.

One of the main purposes of including metals in the computation of stellar atmospheres is their importance as electron donors. Table 17 gives the first few dominant con-

Fig. 4 —Plot of mean molecular weight, μ, versus $\log p_e$ for several values of θ for $B = 8/1$
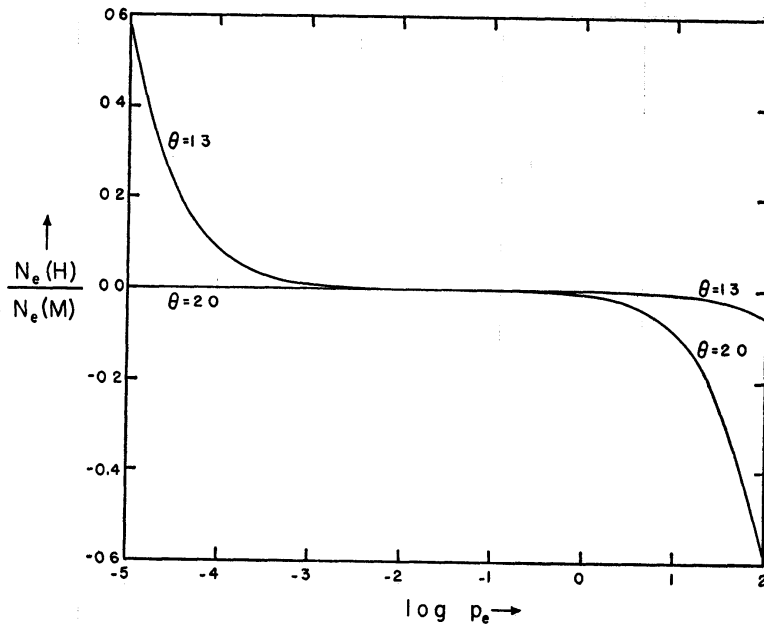

Fig. 5.—Plot of the ratio of electrons contributed by hydrogen to electrons contributed by metals, $N_e(H)/N_e(M)$, versus $\log p_e$ for two values of θ for $B = 8/1$.

tributors of electrons among the metals in the various regions of the $(\log_{10} p_e, \theta)$-diagram; the numbers in the parentheses give the percentage contribution of electrons by the metal. The numbers followed by a colon are less accurate. This table bears out the fact, as suggested by Wildt (1957), that for late-type stars the representative ionization potential should be that corresponding to the alkali metals, if only one metal is considered. However, it may be noted that the effect of taking a higher representative ionization potential can be partially compensated for by taking a higher metal abundance.

TABLE 17

DOMINANT ELECTRON CONTRIBUTORS AMONG METALS

log P_e	θ					
	10	12	14	16	18	20
−5	O(54) C(34)	C(71) Si(13)	Si(51) Mg(32)	Si(45) Mg(40)	Mg(62) Na(10)	Na(37) Ca(26) Al(24)
−4.	C(63) O(20)	C(37) Si(30) Mg(19)	Si(51) Mg(35)	Mg(58) Si(21)	Mg(30) Na(26) Al(19) Ca(18)	Na(55) Ca(29) Al(13)
−3..	C(74) Si(10)	Si(48) Mg(31)	Mg(43) Si(41)	Mg(54) Na(14) Al(10) Ca(10)	Na(47) Ca(29) Al(17)	Na(82) Ca(14)
−2 .	C(56) Si(20) Mg(13)	Si(50) Mg(35)	Mg(59) Si(16)	Na(35) Ca(23) Mg(19) Al(18)	Na(72) Ca(20)	Na(90) K (5)
−1.	Si(42) Mg(28) C(17)	Mg(45) Si(36)	Mg(44) Na(20) Ca(14) Al(13)	Na(61) Ca(26)	Na(86) Ca (8)	Na(71) K(29)
0	Si(48) Mg(35)	Mg(58) Si(14) Na (9)	Na(47) Ca(26) Mg(13) Al(10)	Na(81) Ca(13)	Na(78) K(22)	Na(55:) K(45:)
1	Mg(48) Si(33)	Mg(34) Na(28) Ca(19) Al(11)	Na(72) Ca(19)	Na(77) K(15)	Na(64:) K(36:)	Na(50:) K(50:)
2	Mg(55) Si(13) Na(12)	Na(57) Ca(23) Mg(10)	Na(78) K(11) Ca(11)	Na(71:) K(29:)	Na(50:) K(42:)	K(50:) Na(50:)

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