State	T_e	ω_e	$\omega_e x_e$	B_e	α_e	D_e (10^{-4} cm^{-1})	r_e (Å)	Observed Transitions: Design.	Observed Transitions: ν_{00}	References
$^4He_2$		$\mu = 2.0013016_3$		$D_e^0 = 0.00090$ eV[a]		I.P. = 22.223 eV[c]				NOV 1976 A
				$D_0(a^3\Sigma_u^+) = 1.850$ eV[b]						
				$D_0(A^1\Sigma_u^+) = 2.355$ eV[b]						
		Rydberg series of $np\pi$ $^3\Pi_g$ levels (b, e, i, ℓ, p, r, s, t, u, ...)		$\nu^d = 34302.20 - R/(n-0.071)^2$, n = 2...17.						(23)(39)
		Rydberg series of $np\sigma$ $^3\Sigma_g^+$ levels (c, g, k', n, p', r', s', t', ...)		$\nu^d = 34302.20 - R/(n-0.777)^2$, n = 3...12.						(23)(39)
u $^3\Pi_g$ 10pπ 177291		$[1628.6_9]^e$ Z	(35.2_5)	7.21_2^e	0.22_2^e	$[5.03]^e$	1.081	u→a, R	33189.16 Z	(23)
t' $^3\Sigma_g^+$ 10pσ [177969]				[8.27][f]				t'→a, V	33026.6 Z	(23)
t $^3\Pi_g$ 9pπ 177027		$[1629.1_5]^g$ Z	(35.2_5)	7.21_2^g	0.23_0^g	$[5.07]^g$	1.081	t→a, R	32925.96 Z	(23)
s' $^3\Sigma_g^+$ 9pσ [177636]				[8.04][f]				s'→a, V	32693.2 Z	(23)
s $^3\Pi_g$ 8pπ 176658		$[1629.30]^h$ Z	(35.2_5)	7.213^h	0.223_4^h	5.1^h	1.080_6	s→a, R	32556.66 Z	(23)
r' $^3\Sigma_g^+$ 8pσ [177154]				[7.78][f]				r'→a, V	32211.7 Z	(23)
r $^3\Pi_g$ 7pπ 176117		$(1700.5_6)^i$	(35.2_5)	$[7.104_4]^i$	i	$[5.08]^i$	[1.0889]	r→d, R	11625.3 Z	(39)
								r→a, R	32016.56 Z	(23)
p' $^3\Sigma_g^+$ 7pσ [176421]				[7.543][f]				p'→a,	31478.6 Z	(23)
q { $^3\Delta_u$ 6dδ [176195]; $^3\Pi_u$ 6dπ [(176169)]; $^3\Sigma_u^+$ 6dσ [176120] }				[7.092][j]		[5.0][j]	$[1.089_8]$	q→c, V	20365	(1)(39)
								q→c, R	(20330)	
								q→c, R	20288	
								q→b, V	26483	(1)(39)
								q→b, R	(26466)	
								q→b, R	26409	
p $^3\Pi_g$ 6pπ 175281		1701.18 Z	35.35	7.220^k	0.224	5.14	1.080_1	p→d, R	10788.6_8 Z	(39)
								p→a, R	31179.93 Z	(23)
o $^3\Sigma_u^+$ 6sσ [176001]				[7.109]		[5.1]	$[1.088_5]$	o→c, V	20168.8 Z	(2)(39)
								o→b, R	26290.3 Z	(2)(39)

State	T_e	ω_e	$\omega_e x_e$	B_e	α_e	D_e (10^{-4} cm^{-1})	r_e (Å)	Observed Transitions: Design.	Observed Transitions: ν_{00}	References
$^4He_2$ (continued)										
n $^3\Sigma_g^+$ 6pσ	174389	[1619.52] Z	(36.$_5$)	7.475$_4$[l]	0.249$_0$	[7.2$_1$][m]	1.0615	n→a,	30283.26 Z	(3)(67)
m $^3\Delta_u$ 5dδ	[174863]			[7.09][n] [7.07][o]			[1.09$_1$]	m→c,	V (19039); R (18944); R 18899	(39)
m $^3\Pi_u$ 5dπ	[(174778)]							m→b,	V 25152; R (25070); R 25019	(39)
m $^3\Sigma_u^+$ 5dσ	[174730]									
l $^3\Pi_g$ 5pπ	173884	[1633.9$_6$][p] Z	(35.2$_5$	7.226[p]	0.222[p]	[5.12][p]	1.079$_7$	l→d, R	9393.9 Z	(39)
								l→a, R	29785.31 Z	(23)

He_2:

[a]Average of two independent values for the well depth obtained from measurements of the total (44) and differential (45)(66) elastic scattering cross sections (0.88_8 and 0.90_5 meV, resp.). Ab initio values range from 0.78 to 1.04 meV (33)(43)(51)(53)(56)(64). Both experiment and theory agree that no bound vibrational level exists in the potential well, i.e. $D_0^0 = 0$; see (27)(63). A somewhat higher D_e value (0.99 meV) was derived (61) from the temperature dependence of the relaxation time in dilute ^3He. For measurements of the short-range potential ($0.49 < r(Å) < 1.56$) see (57); the long-range potential is discussed by (28)(29).

[b]Based on $D_0^0(He_2^+)$. From a detailed interpretation of the Hopfield continuum and the 600 Å absorption and emission bands (49) derives $D_e(A\,^1\Sigma_u^+) = 2.50$ eV.

[c]Relative to $He(^1S) + He(^1S)$, i.e. $I.P.(He_2) = I.P.(He) - D_0^0(He_2^+)$. The I.P. for the lowest stable state (a $^3\Sigma_u^+$) is 4.25297 eV.

[d]Giving the v=0,N=0 levels (real or hypothetical) of npσ $^3\Sigma_g^+$ and npπ $^3\Pi_g^-$ relative to 2sσ $^3\Sigma_u^+$, v=0, N=0.

[e]Refers to Π^-. $B_0(^3\Pi^+) \approx 5.6$, strongly affected by l-uncoupling.

[f]Effective value, strongly affected by l-uncoupling.

[g]Refers to Π^-. $B_0(^3\Pi^+) = 5.87$, strongly affected by l-uncoupling.

[h]Refers to Π^-. $B_0(^3\Pi^+) = 6.13$, strongly affected by l-uncoupling.

[i]Constants refer to Π^-; $B_0(^3\Pi^+) = 6.37_5$ affected by l-uncoupling. v=1 is perturbed; approximate deperturbed constants for Π^-: $B_1 = 6.88_6$, $\Delta G(\frac{1}{2}) = 1629.7$.

[j]Strong l-uncoupling. The rotational constants (1) refer to the average of Π^- and Δ^-.

[k]Refers to Π^-. $B_0(^3\Pi^+) = 6.630$ affected by l-uncoupling.

[l]Several small accidental perturbations.

[m]$D_1 = 6.8_2 \times 10^{-4}$, $H_0 = 14._2 \times 10^{-8}$, $H_1 \approx -26 \times 10^{-8}$.

[n]Average of Π^- and Δ^- as given by (39).

[o]Average of Σ^+, Π^+, Δ^+ as given by (39).

[p]Refers to Π^-.

State	T_e	ω_e	$\omega_e x_e$	B_e	α_e	D_e (10^{-4} cm^{-1})	r_e (Å)	Observed Transitions: Design.	Observed Transitions: ν_{00}	References
$^4He_2$ (continued)										
k $^3\Sigma_u^+$ 5sσ	(173698)	[1635.3] Z		7.23_2	0.23		1.079	k→c, V	18683.5 Z	(39)
								k→b, R	$24804._8$ Z	(39)
k' $^3\Sigma_g^+$ 5pσ	172236	1686.90 Z	38.10	7.379[a]	0.349[b]	[5.8]	1.068_4	k'→a, R	28127.58 Z	(67)
j $^3\Delta_u$ 4dδ	171573	1702.2_4[c] Z	35.0_7	7.208_8[c]	0.224_8[d]	5.2[c]	1.0810	j→c, V	16583.18[c] Z	(50)
								R	16400.69[c] Z	
$^3\Pi_u$ 4dπ	171402	1680.9_4[c] Z	40.8_1	7.186_0[c]	0.229_6[e]	5.4[c]	1.0827	R	16316.54[f]	
$^3\Sigma_u^+$ 4dσ	171323	1669.7_9[f]	39.0_9	Strongly perturbed by ℓ-uncoupling and by interaction with the h state.[h]				j→b, V	22704.5[c] Z	(50)
									22522.0[c] Z	
								R	22437.8[f]	
i $^3\Pi_g$ 4pπ	171290	[1637.94][g] Z	(35.2_5)	7.242[g]	0.223[g]	$[5.1_4]$[g]	1.078_5	i→a, R	27193.01 Z	(23)(39)
h $^3\Sigma_u^+$ 4sσ	(170884)	[1637.9] Z		7.26_4[h]	0.23	(5.2_4)	1.077	h→c, V	15870.7 Z	(2)(39)(50)
								h→b, R	21992.2 Z	(2)(39)(50)*
g $^3\Sigma_g^+$ 4pσ	167714	[1589.92] Z	(41)	7.220_7	0.247_8	[5.38][i]	1.0801	g→a, R	23597.00 Z	(67)
f $^3\Delta_u$ 3dδ	166303	1706.82 Z	35.10	7.230[j]	0.227[k]	[5.26][ℓ]	1.079_4	f→c, V	11316.06 Z	(17)
									10864.53 Z	
$^3\Pi_u$ 3dπ	165877[m]	1661.48 Z	44.79	7.136[j]	0.235[n]	[5.34][o]	1.086_5	R	10659.33 Z	
$^3\Sigma_u^+$ 3dσ	165685	1635.77 Z	44.41	7.071[j]	0.246[p]	[5.31][q]	1.091_4	f→b, V	17437.3 Z	(13)*
									16985.8 Z	(13)(39)
								R	16780.6 Z	
e $^3\Pi_g$ 3pπ	165598	1721.22 Z	34.97_0[s]	7.283_8[r]	0.2215[t]	5.22	1.0754	e⟷a,[u] R	21507.26 Z	(36)
d $^3\Sigma_u^+$ 3sσ	164479	1728.01 Z	36.13[v]	7.341_2	0.224_4[w]	5.32	1.0712	d→c, V	9502.7 Z	(13)
								d→b, R_V	15623.1 Z	(13)*
c $^3\Sigma_g^+$ 3pσ	155053	1583.85 Z	52.7_4[x]	7.004_8	0.310_5[y]	[5.56][z]	1.0966	c→a, R	10889.48 Z	(11)
b $^3\Pi_g$ 2pπ	148835	1769.07 Z	35.02[a']	7.447_3[b']	0.219_6[c']	[5.30][d']	1.0635	b→a, R	4768.2 Z	(5)(14)
a $^3\Sigma_u^+$ 2sσ	144048	1808.5_6 Z	38.2_1[e'f']	7.703_6[g']	0.228_1[h']	5.56[i']	1.0457	(a−X)	144935[j']	

He_2:

[a] Several small accidental perturbations.

[b] $\gamma_e = + 0.030$.

[c] The vibrational and rotational constants refer to $^1\Pi^-$ and $^1\Delta^-$ which are less affected by ℓ-uncoupling.

[d] $\gamma_e = - 0.003_8$.

[e] $\gamma_e = - 0.004_6$.

[f] Constants refer to $N' = 1$.

[g] Constants refer to $^3\Pi^-$.

[h] (50) give average effective constants for the four interacting components j($^3\Delta_u^+$, $^3\Pi_u^+$, $^3\Sigma_u^+$) and h $^3\Sigma_u^+$.

[i] $H_0 = 2._0 \times 10^{-8}$.

[j] These constants are corrected for ℓ-uncoupling effects.

[k] $\gamma_e = - 0.004_6$.

[l] $D_1 = 5.28 \times 10^{-4}$, $D_2 = 5.5_0 \times 10^{-4}$, $H_0 = 2.5 \times 10^{-8}$.

[m] Ab initio calculations of f $^3\Pi_u$ and F $^1\Pi_u$ (10)(26) yield excellent agreement with the observed constants and confirm the presence of substantial potential maxima; see also (9).

[n] $\gamma_e = - 0.0069$.

[o] $D_1 = 5.34 \times 10^{-4}$, $D_2 = 5.7_4 \times 10^{-4}$, $H_0 = 2.9 \times 10^{-8}$.

[p] $\gamma_e = - 0.0095$.

[q] $D_1 = 5.34 \times 10^{-4}$, $D_2 = 5.45 \times 10^{-4}$, $H_0 = 0.9_1 \times 10^{-8}$.

[r] The rotational constants refer to $^1\Pi^-$ (36); $B(^3\Pi^-) - B(^3\Pi^+) \approx + 0.072$. Slightly different constants were given by (4) who also derived constants for $^3He_2$.

[s] $\omega_e y_e = - 0.03_8$. See also [r].

[t] $\gamma_e = - 0.0013_8$.

[u] Observed in absorption in a pulsed discharge (19).

[v] $\omega_e y_e = - 0.126_7$.

[w] $\gamma_e = - 0.0027_3$.

[x] $\omega_e y_e = - 1.2566$, $\omega_e z_e = - 0.4875$.

[y] $+ 0.162_9(v+\frac{1}{2})^2 - 0.0655(v+\frac{1}{2})^3$.

[z] $D_1 = 5.76 \times 10^{-4}$, $D_2 = 6.11 \times 10^{-4}$, ...; $H_0 = 1.3_2 \times 10^{-8}$, $H_1 = -0.4_0 \times 10^{-8}$, $H_2 = -5.3 \times 10^{-8}$, ...

[a'] $\omega_e y_e = - 0.048_3$.

[b'] The constants refer to $^3\Pi^-$ and were derived by (13) from the d,f→b bands; $B(^3\Pi^-) - B(^3\Pi^+) \approx + 0.026$. The triplet splitting is partially resolved in the d→b bands (13).

[c'] $\gamma_e = - 0.0017_0$.

[d'] $D_1 = 5.34 \times 10^{-4}$, ...; $H_0 = 2.8_0 \times 10^{-8}$, $H_1 = 3.6_0 \times 10^{-8}$, ...

[e'] $\omega_e y_e = - 0.3_8$ (36).

[f'] There is good experimental (20)(30) and theoretical (7) (21)(48) evidence for a potential maximum in this state. (20) place the maximum at 0.067 eV above the asymptote; the net dissociation energy is 1.850 eV.

[g'] From molecular beam magnetic resonance experiments (58) (65) have determined the triplet splitting for N=1 and 3. The splitting constants (extrapolated to N=0) are $\lambda = - 0.03666$, $\gamma = - 0.000080_8$ cm^{-1}. An ab initio calculation (55) gives $\lambda = - 0.04089$.

[h'] $\gamma_e = - 0.0046_2$ (36).

[i'] $\beta_e = + 0.07 \times 10^{-4}$; $H_e \approx 2.7 \times 10^{-8}$ (36).

[j'] Energy of a $^3\Sigma_u^+$, v=0, N=0 above He(^{1}S) + He(^{1}S), based on $D_0^0(He_2^+) = 19073$ cm^{-1}. See also [c'] p. 297.

State	T_e	ω_e	$\omega_e x_e$	B_e	α_e	D_e (10^{-4} cm^{-1})	r_e (Å)	Observed Transitions: Design.	Observed Transitions: ν_{00}	References
$^4He_2$ (continued)										
S $^1\Pi_g$ 8pπ	[177515]			(7.21)	(0.22)		(1.08_1)	S→A, R	30228.$_6$ Z	(39)
R $^1\Pi_g$ 7pπ	[176983]			(7.22)	(0.22)		(1.08_0)	R→A, R	29696.$_4$ Z	(39)
P $^1\Pi_g$ 6pπ	[176160]			(7.22)	(0.22)		(1.08_0)	P→A, R	28873.$_9$ Z	(39)
M $^1\Delta_u$ 5dδ	[(174838)]			[7.09][a]			$[1.09_1]$	M→B, (24050) (24000) (23960)		(39)
M $^1\Pi_u$ 5dπ	[(174788)]			[7.07][b]						
M $^1\Sigma_u^+$ 5dσ	[(174748)]									
L $^1\Pi_g$ 5pπ	[174794]			(7.23)	(0.22_2)		(1.07_9)	L→A, R	27507.$_8$ Z	(39)
J $^1\Delta_u$ 4dδ	[172416]			[7.097][c]		[5.0]	$[1.089_4]$	J→C, V	14183.90[c] Z	(50)
J $^1\Pi_u$ 4dπ	[172290]			[7.080][c]		[5.4]	$[1.090_8]$	J→C, V	14058.37[c] Z	
								J→C, R	13990.32[d]	
J $^1\Sigma_u^+$ 4dσ	[172222][d]	Strongly perturbed by ℓ-uncoupling and interaction with H $^1\Sigma_u^+$.[e]						J→B, V	21627.9[c] Z	(50)
								J→B,	21502.4[c] Z	
								J→B, R	21434.3[d]	
I $^1\Pi_g$ 4pπ	[172266]			(7.24_2)	(0.22_3)		(1.078)	I→A, R	24979.6 Z	(39)
H $^1\Sigma_u^+$ 4sσ	[171951]			(7.26)[e]	(0.23)		(1.07_7)	H→C, V	13719.5 Z	(39)(50)
								H→B, R	21163.5 Z	(39)(50)
F $^1\Delta_u$ 3dδ	166304	1706.59 Z	35.06	7.230[g]	0.225[h]	[5.20][i]	1.079_4	F→B, V	16360.9 Z	(12)(17)
F $^1\Pi_u$ 3dπ	165971[f]	1670.57 Z	40.03	7.156[g]	0.235	[5.24][j]	1.084_9	F→B,	16008.3 Z	
								F→B, R	15837.5 Z	
F $^1\Sigma_u^+$ 3dσ	(165813)	[1564.25] Z	(40)	7.098[g]	0.246	[5.21][k]	1.089_4			
E $^1\Pi_g$ 3pπ	165911	1721.1_9 Z	34.7_6[l]	7.270_5[m]	0.215_6[n]	5.20	1.0764	E→A, R	19476.61 Z	(36)
D $^1\Sigma_u^+$ 3sσ	165085	1746.43 Z	35.54	7.365	0.218_0[o]	5.24[p]	1.069_4	D→B,[q] R_V	15161.81 Z	(12)
								D→X,[r]	continuum	
C $^1\Sigma_g^+$ 3pσ	157415	1653.43 Z	41.0_4[s]	7.052	0.215[t]	5.08[u]	1.092_9	C→A, R	10945.50 Z	(11)(39)
B $^1\Pi_g$ 2pπ	149914	1765.76 Z	34.39[v]	7.403[w]	0.216[w]	5.02[w]	1.066_7	(B−A)	3501.5[x]	
A $^1\Sigma_u^+$ 2sσ	146365[y]	1861.3_3 Z	35.2_8[z]	7.778_9	0.216_6[a']	5.44	1.0406	A↔X,[b']	147279[c']	(8)(18)(22)
								Hopfield continuum		(38)

State	T_e	ω_e	$\omega_e x_e$	B_e	α_e	D_e (10^{-4} cm^{-1})	r_e (Å)	Observed Transitions: Design.	Observed Transitions: ν_{00}	References
$^4He_2$ (continued)										
X $^1\Sigma_g^+$	0	Repulsive potential with very small well (D_e = 0.90 meV).					2.97[d']			

He_2:

[a] Average of Π^- and Δ^- as given by (39).

[b] Average of Σ^+, Π^+, Δ^+ as given by (39).

[c] These constants refer to Π^- and Δ^- which are less affected by ℓ-uncoupling.

[d] Refers to N=1.

[e] (50) give average effective constants for the four interacting components $J(^1\Delta_u^+, {}^1\Pi_u^+, {}^1\Sigma_u^+)$ and $H\ {}^1\Sigma_u^+$.

[f] See [m] p. 295.

[g] These constants are corrected for ℓ-uncoupling effects.

[h] $\gamma_e = -0.0045$.

[i] $D_1 = 5.26 \times 10^{-4}$, $H_0 = 2.1_8 \times 10^{-8}$.

[j] $D_1 = 5.26 \times 10^{-4}$, $H_0 = 1.9_7 \times 10^{-8}$.

[k] $D_1 = 5.29 \times 10^{-4}$.

[ℓ] $\omega_e y_e = -0.02_3$.

[m] The rotational constants refer to Π^- (36); $B(\Pi^-) - B(\Pi^+) \approx +0.044$.

[n] $\gamma_e = -0.0022_7$.

[o] $\gamma_e = -0.005_9$.

[p] $\beta_e = +0.1_9 \times 10^{-4}$.

[q] Franck-Condon factors (25).

[r] The weak maximum near 676 Å in the Hopfield continuum is ascribed by (37) to the transition D→X.

[s] $\omega_e y_e = +0.354_9$, $\omega_e z_e = -0.131_5$. Calculations of (47) give a potential hump of 0.22 eV at 2.09 Å; see also (59) and (60).

[t] $\gamma_e = -0.0111$.

[u] $\beta_e = +0.1_0 \times 10^{-4}$; $H_0 = 1.7_2 \times 10^{-8}$, ...

[v] $\omega_e y_e = -0.026_7$ (12).

[w] B_e refers to Π^-; $B(\Pi^-) - B(\Pi^+) = +0.019$; $\gamma_e = -0.001_5$, $\beta_e = +0.05 \times 10^{-4}$ (12).

[x] From (39).

[y] RKR potential curve (34)[see also (39)]; ab initio potential (42). The latter gives vibrational and rotational levels in good agreement with the experimental values. (8) have established, from the absorption and emission bands near 600 Å, a potential maximum of 0.059 eV in the A $^1\Sigma_u^+$ state. Theoretical work by (15)(16)(47) gives maxima of 0.084, 0.153, 0.061 eV, respectively; see also (59)(60).

[z] $\omega_e y_e = -0.13_6$ (36).

[a'] $\gamma_e = -0.0027_3$ (36).

[b'] Transitions from the low vibrational levels of A $^1\Sigma_u^+$ to X $^1\Sigma_g^+$ give rise to the Hopfield continuum; see MOLSPEC 1, 404. Transitions from the high vibrational levels as well as the continuous range of energy levels of A $^1\Sigma_u^+$ to X $^1\Sigma_g^+$ give rise to diffuse bands near 600 Å observed in emission (18) (22) and absorption (8)(38) with quite different intensity distribution. See also (6)(37) and (31)(52)(54). Observed absorption coefficients near 600 Å (38) agree fairly well with those predicted by (41).

[c'] Energy of the v=0,N=0 level of A $^1\Sigma_u^+$ relative to He(^{1}S) + He(^{1}S), calculated from the corresponding value for a $^3\Sigma_u^+$ by

(continued p. 299)