On the existence of the H3 tautomer of adenine in aqueous solution. Rationalizations based on hybrid quantum mechanics/molecular mechanics predictions

Supporting Information

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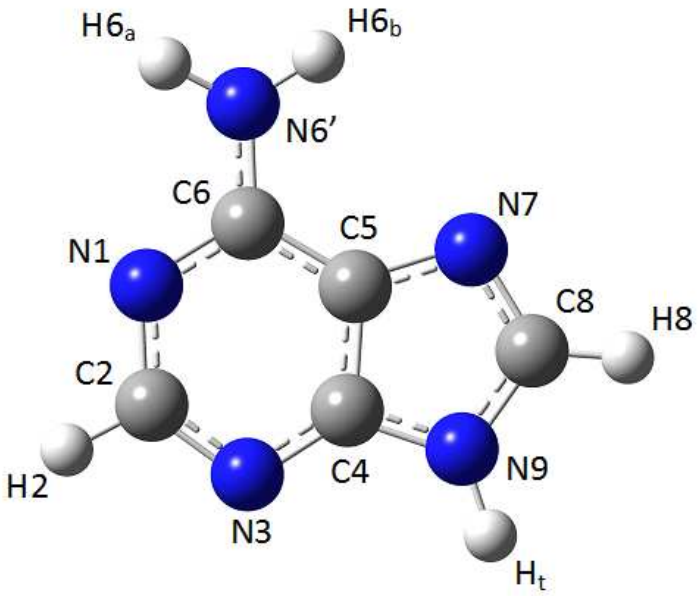

Figure 1: The atom labeling in adenine. The H_t proton is bonded to N9, N7 and N3 in the H9-A, H7-A and H3-A tautomers of adenine, respectively.

Table 1: The *xyz* coordinates (in Å) of the H9-A tautomer of adenine optimized using MP2/aug-cc-pVTZ method in C_s and C_1 symmetries.

Atom	x	y	z
		C_s	
N1	1.643187	-1.123608	0.000000
N3	-0.636609	-1.783016	0.000000
N6'	2.341180	1.062407	0.000000
N7	-0.640229	1.763829	0.000000
N9	-2.126024	0.124109	0.000000
C2	0.654169	-2.004565	0.000000
C4	-0.910883	-0.487128	0.000000
C5	0.000000	0.538649	0.000000
C6	1.346285	0.166102	0.000000
C8	-1.882508	1.469813	0.000000
H2	0.958133	-3.034439	0.000000
$H6_a$	3.278106	0.745200	0.000000
$H6_b$	2.142535	2.031091	0.000000
H8	-2.682938	2.179419	0.000000
H_t	-3.008751	-0.324548	0.000000
		C_1	
N1	1.922501	0.515156	0.001616
N3	-0.009480	1.893201	0.000128
N6'	1.857147	-1.779705	-0.022245
N7	-1.188532	-1.451767	0.000180
N9	-2.046935	0.587808	0.000657
C2	1.281636	1.674489	0.001942
C4	-0.697986	0.761588	-0.000995
C5	-0.178487	-0.508196	-0.002324
C6	1.214928	-0.602948	-0.003314
C8	-2.263075	-0.762516	0.001482
H2	1.909843	2.545298	0.004897
$H6_a$	2.842007	-1.787258	0.073528
$H6_b$	1.347647	-2.622252	0.073268
H8	-3.253388	-1.166711	0.003436
H_t	-2.731115	1.303567	0.001768

Table 2: The *xyz* coordinates (in Å) of the H9-A, H7-A and H3-A tautomers of adenine fully optimized using MP2/aug-cc-pVTZ/PCM method in aqueous solution.

Atom	x	y	z
		H9-A	
N1	1.936876	0.541445	0.001513
N3	-0.045191	1.921972	0.001090
N6'	1.892853	-1.780707	-0.043620
N7	-1.150632	-1.485898	-0.001906
N9	-2.076697	0.562356	0.002280
C2	1.272159	1.714693	0.001733
C4	-0.722813	0.762913	-0.000125
C5	-0.170166	-0.521506	-0.002723
C6	1.235136	-0.603204	-0.002392
C8	-2.279356	-0.783663	0.001133
H2	1.897873	2.602814	0.004710
$H6_a$	2.891080	-1.775587	0.138241
$H6_b$	1.382771	-2.635291	0.148518
H8	-3.275573	-1.207961	0.002725
H_t	-2.806369	1.286453	0.004553
		H7-A	
N1	1.947906	0.483621	-0.000876
N3	0.022139	1.938817	0.003703
N6'	1.826027	-1.835810	-0.053498
N7	-1.257130	-1.322408	-0.004404
N9	-2.104868	0.756467	0.004414
C2	1.326462	1.684450	-0.000278
C4	-0.730136	0.818559	0.003809
C5	-0.188522	-0.474228	-0.000554
C6	1.208139	-0.630618	-0.001178
C8	-2.372984	-0.540389	-0.001206
H2	1.989505	2.545067	-0.000227
$H6_a$	2.821740	-1.843165	0.148231
$H6_b$	1.309680	-2.666170	0.218805
H8	-3.364322	-0.976122	-0.003337
H_t	-1.252881	-2.351071	-0.012396
		H3-A	
N1	1.934225	0.458665	-0.000538
N3	0.016186	1.832656	0.000460
N6'	1.802264	-1.845644	-0.001257
N7	-1.230743	-1.469870	-0.000233
N9	-2.138667	0.666242	0.000270
C2	1.342823	1.639507	-0.000113
C4	-0.796525	0.738928	0.000277
C5	-0.226146	-0.546885	-0.000173
C6	1.172437	-0.668427	-0.000282
C8	-2.331528	-0.684758	-0.000302
H2	1.955565	2.535669	-0.000079
$H6_a$	2.816410	-1.876154	0.005037
$H6_b$	1.274550	-2.710927	0.007432
H8	-3.330270	-1.105462	-0.000495
H_t	-0.365479	2.792337	0.000758

Table 3: Absolute ^{15}N NMR isotropic shielding constants of H9-A in vacuum (MP2/aug-cc-pVTZ optimized C_1 geometry in vacuum, see Table 1) calculated using KT3 functional and different basis sets. Also shown are the corresponding relative ^{15}N NMR spectra with respect to σ^{N7}. t-dzp and t-tzp denote Turbomole-DZP and Turbomole-TZP basis sets, respectively, whereas (a)(c)xz, x=d,t,q, denote (aug-)cc-p(C)VXZ basis sets, respectively. See Figure 1 for atom labeling.

	t-dzp	t-tzp	dz	cdz	adz	tz	ctz	atz	qz	cqz	aqz
σ^{N1}	46.0	27.1	42.0	34.0	41.2	29.1	21.4	30.8	25.5	18.9	24.4
σ^{N3}	52.3	34.0	48.1	40.2	49.2	36.1	28.3	38.6	32.7	26.4	32.2
$\sigma^{N6'}$	197.4	189.6	197.1	193.6	196.0	189.0	185.9	188.3	186.6	183.7	185.6
σ^{N7}	41.0	20.0	37.3	28.4	35.9	22.3	14.1	24.9	18.9	12.2	18.2
σ^{N9}	124.8	111.6	123.5	118.2	122.6	112.8	107.4	112.5	109.4	104.8	108.3
δ^{N1}	5.0	7.1	4.7	5.6	5.3	6.8	7.3	5.9	6.6	6.7	6.2
δ^{N3}	11.3	14.0	10.8	11.8	13.3	13.8	14.2	13.7	13.8	14.2	14.0
$\delta^{N6'}$	156.4	169.6	159.8	165.2	160.1	166.7	171.8	163.4	167.7	161.5	167.4
δ^{N7}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
δ^{N9}	83.8	91.6	86.2	89.8	86.7	93.3	93.3	87.6	90.5	92.6	90.1

Table 4: B97-2 based isotropic ^2J NMR spin-spin coupling constants of the MP2/aug-cc-pVTZ optimized C_1 geometry of H9-A (see Table 1) for different basis sets. atz-J denotes aug-cc-pVTZ-J basis set. See Figure 1 for atom labeling.

	Huz-IIsu2	Huz-IIIsu3	Huz-IVsu4	atz-J
^2J(N1-H11)	-16.20	-16.35	-16.43	-16.57
^2J(N2-H11)	-16.33	-16.58	-16.64	-16.78
^2J(N4-H15)	-12.58	-12.80	-12.91	-12.97
^2J(N5-H15)	-9.32	-9.53	-9.59	-9.72

Table 5: CAM-B3LYP based vertical excitation energies, E, in eV and dimensionless oscillator strengths in length gauge, f, of H9-A tautomer geometry-optimized at the MP2/aug-cc-pVTZ level in C_s symmetry (see Table 1). Basis sets used are the Dunning-type correlation-consistent basis sets (d-)(aug-)cc-pVXZ, X = D,T. The three top rows contain data for the three lowest excitation energies in H9-A, and the fourth row refers to the first subsequent intense $\pi \rightarrow \pi^*$ transition.

	cc-pVDZ		aug-cc-pVDZ		daug-cc-pVDZ		aug-cc-pVTZ		daug-cc-pVTZ	
	E	f	E	f	E	f	E	f	E	f
$n \rightarrow \pi^*$	5.463	0.0002	5.438	0.0007	5.436	0.0008	5.438	0.0007	5.436	0.0007
$\pi \rightarrow \pi^*$	5.676	0.17	5.490	0.28	5.474	0.28	5.483	0.28	5.476	0.27
$\pi \rightarrow \pi^*$	5.792	0.12	5.617	0.01	5.607	0.01	5.613	0.01	5.609	0.01
$\pi \rightarrow \pi^*$	6.978	0.40	6.663	0.41	6.627	0.38	6.645	0.39	6.632	0.38

Table 6: Force field parameters for the H9-A, H7-A and H3-A tautomers of adenine used in the MD simulations. Partial point charges, q, are given in au, isotropic polarizabilites, α, in Å^3, Lennard-Jones parameters ε and σ in kcal/mol and Å, respectively. See Figure 1 for atom labeling.

	H9-A		H7-A		H3-A			
Atom	q	α	q	α	q	α	ε	σ
N1	-0.72593	1.1731	-0.71794	1.1854	-0.63076	1.1812	0.17	3.25
N3	-0.74900	1.2763	-0.76100	1.2666	-0.57686	1.1452	0.17	3.25
N6'	-0.57561	1.1197	-0.59374	1.1112	-0.54607	1.1090	0.17	3.25
N7	-0.55780	1.1841	-0.45018	1.0250	-0.69986	1.2286	0.17	3.25
N9	-0.48080	1.0217	-0.65105	1.1931	-0.76462	1.2653	0.17	3.25
C2	0.58921	1.3193	0.58673	1.3030	0.41210	1.3448	0.08	3.50
C4	0.60762	1.3398	0.85975	1.3381	0.62999	1.4187	0.08	3.50
C5	0.02634	1.4050	-0.20247	1.4053	0.06547	1.5274	0.08	3.50
C6	0.55651	1.5335	0.57757	1.5105	0.51503	1.5984	0.08	3.50
C8	0.30453	1.2432	0.34929	1.2266	0.55137	1.3030	0.08	3.50
H2	0.01494	0.4374	0.01429	0.4363	0.06090	0.4036	0.05	2.50
$H6_a$	0.29728	0.3587	0.29868	0.3567	0.29555	0.3494	0.00	0.00
$H6_b$	0.27534	0.3025	0.26785	0.3199	0.29651	0.2851	0.00	0.00
H8	0.07478	0.4307	0.06808	0.4240	0.01644	0.4455	0.05	2.50
H_t	0.34259	0.3416	0.35414	0.3243	0.37481	0.3306	0.00	0.00

Table 7: Force field parameters for water molecules used in the MD simulations and QM/MM calculations. Partial point charges, q, are given in au, isotropic polarizabilites, α, in Å^3, Lennard-Jones parameters ε and σ in kcal/mol and Å, respectively.

Atom	q	α	ε	σ
O	-0.6690	1.440	0.1555	3.166
H	0.3345	0.000	0.0000	0.000