Environmental Effects on the Enhancement in Natural and Damaged DNA Nucleobase Acidity Due to Discrete Hydrogen-Bonding Interactions

Ken C. Hunter[a] and Stacey D. Wetmore[b]

[a]*Department of Chemistry, Mount Allison University, 63C York Street, Sackville, New Brunswick, E4L 1G8, Canada*

[b]*Department of Chemistry & Biochemistry, 4401 University Drive, Lethbridge, Alberta, T1K 3M4, Canada*

Supporting Information

(Tables S1 – S5, 11 pages)

Table S1: Acidity, and the Corresponding Effects of Solvation on the Acidity (Δ_{solv}), of Uracil in a Variety of Media (kJ mol^{-1}).

		Gas-Phase Geometries[a]				Solvent-Phase Geometries[b]			
		Onsager		PCM		Onsager		PCM	
Solvent System	ε[c]	Acidity[d]	Δ_{solv}[e]	Acidity[d]	Δ_{solv}[e]	Acidity[d]	Δ_{solv}[e]	Acidity[d]	Δ_{solv}[e]
gas	1	1389.4		1389.4		1389.4		1389.4	
argon (Ar)	1.43	1391.4	-2.0	1334.7	54.7	1391.3	-1.9	1335.3	54.1
krypton (Kr)	1.519	1391.7	-2.3	1327.4	62.0	1391.6	-2.2	1328.0	61.4
heptane (C_7H_{16})	1.92	1392.9	-3.5	1302.5	86.9	1392.8	-3.4	1303.5	85.9
benzene (C_6H_6)	2.247	1393.6	-4.2	1289.2	100.2	1393.5	-4.1	1290.4	99.0
ether ($CH_3CH_2OCH_2CH_3$)	4.335	1396.1	-6.7	1251.9	137.5	1395.9	-6.5	1254.0	135.4
chloroform ($CHCl_3$)	4.9	1396.5	-7.1	1247.3	142.1	1396.3	-6.9	1249.6	139.8
tetrahydrofuran (THF)	7.58	1397.5	-8.1	1234.9	154.5	1397.4	-8.0	1237.9	151.5
ethanol (CH_3CH_2OH)	24.55	1399.1	-9.7	1219.6	169.8	1398.9	-9.5	1223.6	165.8
methanol (CH_3OH)	32.64	1399.2	-9.8	1217.9	171.5	1399.1	-9.7	1222.0	167.4
dimethylsulfoxide (DMSO)	46.7	1399.4	-10.0	1216.3	173.1	1399.3	-9.9	1220.3	169.1
water (H_2O)	78.39	1399.6	-10.2	1214.8	174.6	1399.4	-10.0	1219.0	170.4

[a]The N1 acidities were obtained from Onsager or PCM B3LYP/6-311+G(2d,p) single-point calculations on B3LYP/6-31+G(d,p) geometries optimized in the gas phase. [b]The N1 acidities were obtained from Onsager or PCM B3LYP/6-311+G(2d,p) single-point calculations on B3LYP/6-31+G(d,p) geometries optimized in the solvent phase. [c]Dielectric constant of the surrounding media. [d]Acidity is defined as the deprotonation enthalpy. [e]Δ_{solv} is defined as the difference in the gas and solvent phase acidities, where a negative value implies a decrease in acidity upon solvation.

Table S2: Acidity of the Uracil-Water O2(N3) Complex (kJ mol^{-1}) Calculated in a Variety of Media Using PCM and Geometries Obtained With Different Basis Set.[a]

		6-31+G(d,p) Geometries				6-31G(d) Geometries			
		Gas Phase [b]		Solvent Phase [c]		Gas Phase [b]		Solvent Phase [c]	
	ε[d]	Acidity[e]	Δ_{solv}[f]	Acidity[e]	Δ_{solv}[f]	Acidity[e]	Δ_{solv}[f]	Acidity[e]	Δ_{solv}[f]
Gas	1	1369.1		1369.1		1371.0		1371.0	
Ar	1.43	1317.8	51.3	1318.4	50.7	1319.9	51.1	1320.4	50.6
Kr	1.519	1310.9	58.2	1311.6	57.5	1313.0	58.0	1313.6	57.4
C_7H_{16}	1.92	1288.0	81.1	1289.6	79.5	1290.2	80.8	1291.1	79.9
C_6H_6	2.247	1275.3	93.8	1277.1	92.0	1277.7	93.3	1278.8	92.2
$CH_3CH_2OCH_2CH_3$	4.335	1240.3	128.8			1243.1	127.9	1244.8	126.2
$CHCl_3$	4.9	1236.0	133.1			1238.8	132.2	1240.9	130.1
THF	7.58	1224.5	144.6			1227.5	143.5	1230.1	140.9
CH_3CH_2OH	24.55	1209.8	159.3			1213.3	157.7	1217.0	154.0
CH_3OH	32.64	1207.8	161.3			1211.6	159.4	1215.2	155.8
DMSO	46.7	1207.1	162.0			1210.4	160.6	1214.0	157.0
H_2O	78.39	1203.9	165.2			1208.8	162.2	1212.6	158.4

[a]See Figure 2 for the structure of the uracil-water O2(N3) complex, where XH = H_2O. [b]The N1 acidities were obtained from PCM B3LYP/6-311+G(2d,p) single-point calculations on B3LYP geometries optimized in the gas phase. [c]The N1 acidities were obtained from PCM B3LYP/6-311+G(2d,p) single-point calculations on B3LYP geometries optimized in the solvent phase. [d]Dielectric constant of the surrounding media. [e]Acidity is defined as the deprotonation enthalpy. [f]Δ_{solv} is defined as the difference in the gas and solvent phase acidities, where a positive value implies an increase in acidity upon solvation.

Table S3: Calculated (N1) Acidities (kJ mol^{-1}) of Uracil Complexes with Hydrogen Fluoride, Water, and Ammonia in Ether and Water.[a,b]

			Ether[c]				Water[d]			
O2(N3)	O4(N3)	O4(C5)	Acidity[e]	Δ_{XH} [f]	Additivity[g]	Δ[h]	Acidity[e]	Δ_{XH} [f]	Additivity[g]	Δ[h]
			1251.9				1214.8			
HF			1213.1	38.8			1181.2	33.6		
	HF		1219.8	32.1			1184.3	30.5		
		HF	1222.3	29.6			1191.3	23.5		
H_2O			1240.4	11.5			1204.0	10.8		
	H_2O		1243.2	8.7			1204.7	10.1		
		H_2O	1241.2	10.7			1207.1	7.7		
NH_3			1258.4	-6.5			1218.1	-3.3		
	NH_3		1258.2	-6.3			1217.2	-2.4		
		NH_3	1248.4	3.5			1210.6	4.2		
HF		HF	1185.7	66.2	68.4	-2.2	1158.3	56.5	57.1	-0.6
HF		H_2O	1203.5	48.4	49.5	-1.1	1173.0	41.8	41.3	0.5
HF		NH_3	1210.5	41.4	42.3	-0.9	1177.1	37.7	37.8	-0.1
H_2O		HF	1214.6	37.3	41.1	-3.8	1184.4	30.4	34.3	-3.9
H_2O		H_2O	1231.1	20.8	22.2	-1.4	1197.6	17.2	18.5	-1.3
H_2O		NH_3	1237.7	14.2	15.0	-0.8	1200.7	14.1	15.0	-0.9
NH_3		HF	1223.4	28.5	23.1	5.4	1190.8	24.0	20.2	3.8
NH_3		H_2O	1252.9	-1.0	4.2	-5.2	1217.8	-3.0	4.4	-7.4
NH_3		NH_3	1258.2	-6.3	-3.0	-3.3	1219.4	-4.6	0.9	-5.5
	HF	HF	1201.2	50.7	61.7	-11.0	1172.7	42.1	54.0	-11.9
	HF	H_2O	1212.5	39.4	42.8	-3.4	1178.6	36.2	38.2	-2.0
	HF	NH_3	1218.2	33.7	35.6	-1.9	1181.5	33.3	34.7	-1.4
	H_2O	HF	1220.6	31.3	38.3	-7.0	1189.0	25.8	33.6	-7.8
	H_2O	H_2O	1234.8	17.1	19.4	-2.3	1199.4	15.4	17.8	-2.4
	H_2O	NH_3	1242.5	9.4	12.2	-2.8	1202.7	12.1	14.3	-2.2
	NH_3	HF	1240.7	11.2	23.3	-12.1	1204.1	10.7	21.1	-10.4
	NH_3	H_2O	1251.2	0.7	4.4	-3.7	1214.5	0.3	5.3	-5.0
	NH_3	NH_3	1258.3	-6.4	-2.8	-3.6	1215.4	-0.6	1.8	-2.4

[a]The N1 acidities were obtained from PCM B3LYP/6-311+G(2d,p) single-point calculations on gas-phase B3LYP/6-31+G(d,p) geometries. [b]See Figure 2 for site notation. [c]Dielectric constant of 4.335 implemented. [d]Dielectric constant of 78.39 implemented. [e]Acidity is defined as the deprotonation enthalpy. [f]The effect of XH on the acidity of uracil, which is calculated as difference in the acidity of free uracil and the uracil-XH complex. [g]The additive effects of two small molecules, which is calculated as the sum of the individual Δ_{XH}. [h]The deviation from additivity, which is calculated as Δ_{XH} minus Additivity.

Table S4: Calculated (N9) Acidities (kJ mol^{-1}) of Guanine in Complexes with Hydrogen Fluoride, Water, and Ammonia in Ether and Water.[a,b]

			Ether[c]				Water[d]			
O6-N7	**N3(N2)**	**O6(N1)**	Acidity[e]	Δ_{XH}[f]	Additivity[g]	Δ[h]	Acidity[e]	Δ_{XH}[f]	Additivity[g]	Δ[h]
H_2O			1254.1	11.2			1221.4	4.7		
HF			1232.7	32.6			1198.9	27.2		
NH_3			1264.8	0.5			1229.7	-3.6		
	H_2O		1255.2	10.1			1221.2	4.9		
	HF		1241.8	23.5			1208.8	17.3		
	NH_3		1268.5	-3.2			1231.4	-5.3		
		H_2O	1257.3	8.0			1219.4	6.7		
		HF	1241.6	23.7			1206.4	19.7		
		NH_3	1270.7	-5.4			1229.9	-3.8		
H_2O	H_2O		1245.0	20.3	21.3	-1.0	1217.1	9.0	9.6	-0.6
H_2O	HF		1232.9	32.4	34.7	-2.3	1207.3	18.8	22.0	-3.2
H_2O	NH_3		1258.2	7.1	8.0	-0.9	1227.4	-1.3	-0.6	-0.7
HF	H_2O		1226.9	38.4	42.7	-4.3	1199.5	26.6	32.1	-5.5
HF	HF		1215.2	50.1	56.1	-6.0	1189.7	36.4	44.5	-8.1
HF	NH_3		1239.9	25.4	29.4	-4.0	1209.4	16.7	21.9	-5.2
NH_3	H_2O		1255.5	9.8	10.6	-0.8	1225.6	0.5	1.3	-0.8
NH_3	HF		1241.8	23.5	24.0	-0.5	1214.2	11.9	13.7	-1.8
NH_3	NH_3		1268.2	-2.9	-2.7	-0.2	1235.2	-9.1	-8.9	-0.2
H_2O		H_2O	1248.8	16.5	19.2	-2.7	1216.7	9.4	11.4	-2.0
H_2O		HF	1233.0	32.3	34.9	-2.6	1205.2	20.9	24.4	-3.5
H_2O		NH_3	1260.3	5.0	5.8	-0.8	1228.1	-2.0	0.9	-2.9
HF		H_2O	1230.5	34.8	40.6	-5.8	1198.6	27.5	33.9	-6.4
HF		HF	1213.4	51.9	56.3	-4.4	1185.4	40.7	46.9	-6.2
HF		NH_3	1241.8	23.5	27.2	-3.7	1206.9	19.2	23.4	-4.2
NH_3		H_2O	1258.6	6.7	8.5	-1.8	1223.9	2.2	3.1	-0.9
NH_3		HF	1240.5	24.8	24.2	0.6	1210.2	15.9	16.1	-0.2
NH_3		NH_3	1270.5	-5.2	-4.9	-0.3	1233.3	-7.2	-7.4	0.2
	H_2O	H_2O	1249.7	15.6	18.1	-2.5	1216.8	9.3	11.6	-2.3
	H_2O	HF	1234.1	31.2	33.8	-2.6	1205.3	20.8	24.6	-3.8
	H_2O	NH_3	1261.8	3.5	4.7	-1.2	1225.9	0.2	1.1	-0.9
	HF	H_2O	1236.0	29.3	31.5	-2.2	1204.0	22.1	24.0	-1.9
	HF	HF	1222.3	43.0	47.2	-4.2	1195.8	30.3	37.0	-6.7
	HF	NH_3	1250.3	15.0	18.1	-3.1	1216.6	9.5	13.5	-4.0
	NH_3	H_2O	1262.3	3.0	4.8	-1.8	1226.3	-0.2	1.4	-1.6
	NH_3	HF	1248.0	17.3	20.5	-3.2	1216.4	9.7	14.4	-4.7
	NH_3	NH_3	1273.5	-8.2	-8.6	0.4	1234.4	-8.3	-9.1	0.8
H_2O	H_2O	H_2O	1240.3	25.0	29.3	-4.3	1212.6	13.5	16.3	-2.8
H_2O	H_2O	HF	1225.3	40.0	45.0	-5.0	1201.5	24.6	29.3	-4.7
H_2O	H_2O	NH_3	1251.3	14.0	15.9	-1.9	1221.2	4.9	5.8	-0.9
H_2O	HF	H_2O	1229.2	36.1	42.7	-6.6	1203.9	22.2	28.7	-6.5
H_2O	HF	HF	1213.5	51.8	58.4	-6.6	1192.5	33.6	41.7	-8.1
H_2O	HF	NH_3	1240.7	24.6	29.3	-4.7	1213.0	13.1	18.2	-5.1
H_2O	NH_3	H_2O	1252.8	12.5	16.0	-3.5	1222.5	3.6	6.1	-2.5
H_2O	NH_3	HF	1239.6	25.7	31.7	-6.0	1213.6	12.5	19.1	-6.6
H_2O	NH_3	NH_3	1263.5	1.8	2.6	-0.8	1230.3	-4.2	-4.4	0.2

HF	H_2O	H_2O	1222.1	43.2	50.7	-7.5	1195.1	31.0	38.8	-7.8
HF	H_2O	HF	1207.6	57.7	66.4	-8.7	1184.5	41.6	51.8	-10.2
HF	H_2O	NH_3	1232.9	32.4	37.3	-4.9	1203.0	23.1	28.3	-5.2
HF	HF	H_2O	1211.7	53.6	64.1	-10.5	1186.8	39.3	51.2	-11.9
HF	HF	HF	1189.4	75.9	79.8	-3.9	1168.0	58.1	64.2	-6.1
HF	HF	NH_3	1223.0	42.3	50.7	-8.4	1195.5	30.6	40.7	-10.1
HF	NH_3	H_2O	1234.7	30.6	37.4	-6.8	1204.8	21.3	28.6	-7.3
HF	NH_3	HF	1222.6	42.7	53.1	-10.4	1197.1	29.0	41.6	-12.6
HF	NH_3	NH_3	1244.8	20.5	24.0	-3.5	1212.0	14.1	18.1	-4.0
NH_3	H_2O	H_2O	1249.8	15.5	18.6	-3.1	1219.8	6.3	8.0	-1.7
NH_3	H_2O	HF	1231.8	33.5	34.3	-0.8	1206.3	19.8	21.0	-1.2
NH_3	H_2O	NH_3	1261.1	4.2	5.2	-1.0	1228.7	-2.6	-2.5	-0.1
NH_3	HF	H_2O	1238.1	27.2	32.0	-4.8	1210.5	15.6	20.4	-4.8
NH_3	HF	HF	1218.6	46.7	47.7	-1.0	1195.3	30.8	33.4	-2.6
NH_3	HF	NH_3	1250.1	15.2	18.6	-3.4	1220.0	6.1	9.9	-3.8
NH_3	NH_3	H_2O	1262.4	2.9	5.3	-2.4	1229.6	-3.5	-2.2	-1.3
NH_3	NH_3	HF	1247.3	18.0	21.0	-3.0	1218.6	7.5	10.8	-3.3
NH_3	NH_3	NH_3	1272.7	-7.4	-8.1	0.7	1237.5	-11.4	-12.7	1.3

[a]The N9 acidities were obtained from PCM B3LYP/6-311+G(2d,p) single-point calculations on gas-phase B3LYP/6-31+G(d,p) geometries. [b]See Figure 3 for site notation. [c]Dielectric constant of 4.335 implemented. [d]Dielectric constant of 78.39 implemented. [e]Acidity is defined as the deprotonation enthalpy. [f]The effect of XH on the acidity of uracil, which is calculated as difference in the acidity of free uracil and the uracil-XH complex. [g]The additive effects of two small molecules, which is calculated as the sum of the individual Δ_{XH}. [h]The deviation from additivity, which is calculated as Δ_{XH} minus Additivity.

Table S5: Calculated (N9) Acidities (kJ mol^{-1}) of 8-oxoguanine in Complexes with Hydrogen Fluoride, Water, and Ammonia in Ether and Water.[a,b]

				Gas[c]				Ether[d]				Water[e]			
O6(N7)	**O8(N7)**	**N3(N2)**	**O6(N1)**	Acidity[f]	Δ_{XH} [g]	Additivity[h]	Δ[i]	Acidity[f]	Δ_{XH} [g]	Additivity[h]	Δ[i]	Acidity[f]	Δ_{XH} [g]	Additivity[h]	Δ[i]
H_2O				1401.8	6.6			1264.8	3.2			1221.9	2.6		
HF				1379.6	28.7			1246.6	21.4			1206.5	18.0		
NH_3				1421.1	-12.8			1277.1	-9.1			1230.7	-6.2		
	H_2O			1389.1	19.2			1255.9	12.1			1213.0	11.5		
	HF			1360.1	48.3			1229.6	38.4			1192.4	32.1		
	NH_3			1412.9	-4.6			1274.7	-6.7			1229.8	-5.3		
		H_2O		1387.8	20.5			1258.8	9.2			1220.5	4.0		
		HF		1370.3	38.1			1243.9	24.1			1206.4	18.1		
		NH_3		1407.1	1.2			1271.9	-3.9			1230.3	-5.8		
			H_2O	1398.1	10.3			1261.3	6.7			1218.9	5.6		
			HF	1371.1	37.2			1240.8	27.2			1201.6	22.9		
			NH_3	1417.5	-9.1			1273.9	-5.9			1228.3	-3.8		
H_2O	HF			1359.5	48.9	54.9	-6.0	1237.4	30.6	41.6	-11.0	1200.0	24.5	34.7	-10.2
HF	H_2O			1356.4	51.9	47.9	4.0	1239.8	28.2	33.5	-5.3	1201.4	23.1	29.5	6.4
HF	HF			1336.5	71.8	77.0	-5.2	1222.6	45.4	59.8	-14.4	1189.1	35.4	50.1	14.7
H_2O		H_2O		1382.8	25.5	27.1	-1.6	1257.6	10.4	12.4	-2.0	1219.6	4.9	6.6	1.7
H_2O		HF		1366.0	42.3	44.7	-2.4	1243.7	24.3	27.3	-3.0	1207.4	17.1	20.7	3.6
H_2O		NH_3		1401.4	7.0	7.8	-0.8	1268.8	-0.8	-0.7	-0.1	1227.4	-2.9	-3.2	-0.3
HF		H_2O		1361.5	46.8	49.2	-2.4	1240.9	27.1	30.6	-3.5	1205.7	18.8	22.0	3.2
HF		HF		1343.5	64.9	66.8	-1.9	1227.7	40.3	45.5	-5.2	1194.8	29.7	36.1	6.4
HF		NH_3		1381.3	27.1	29.9	-2.8	1255.0	13.0	17.5	-4.5	1216.9	7.6	12.2	4.6
NH_3		H_2O		1401.3	7.1	7.7	-0.6	1267.9	0.1	0.1	0.0	1226.1	-1.6	-2.2	-0.6
NH_3		HF		1385.0	23.4	25.3	-1.9	1256.4	11.6	15.0	-3.4	1217.0	7.5	11.9	4.4
NH_3		NH_3		1417.7	-9.3	-11.6	2.3	1278.5	-10.5	-13.0	2.5	1234.0	-9.5	-12.0	-2.5
H_2O			H_2O	1393.6	14.7	16.9	-2.2	1261.5	6.5	9.9	-3.4	1219.6	4.9	8.2	3.3
H_2O			HF	1370.5	37.8	43.8	-6.0	1243.8	24.2	30.4	-6.2	1205.9	18.6	25.5	6.9
H_2O			NH_3	1411.3	-2.9	-2.5	-0.4	1271.0	-3.0	-2.7	-0.3	1226.3	-1.8	-1.2	0.6
HF			H_2O	1375.1	33.2	39.0	-5.8	1246.6	21.4	28.1	-6.7	1207.4	17.1	23.6	6.5
HF			HF	1351.2	57.2	65.9	-8.7	1230.5	37.5	48.6	-11.1	1195.8	28.7	40.9	12.2
HF			NH_3	1392.8	15.6	19.6	-4.0	1257.4	10.6	15.5	-4.9	1215.7	8.8	14.2	5.4
NH_3			H_2O	1411.7	-3.4	-2.5	-0.9	1271.7	-3.7	-2.4	-1.3	1226.2	-1.7	-0.6	1.1
NH_3			HF	1387.4	21.0	24.4	-3.4	1254.5	13.5	18.1	-4.6	1213.8	10.7	16.7	6.0

NH_3			NH_3	1429.3	-21.0	-21.9	0.9	1282.9	-14.9	-15.0	0.1	1234.4	-9.9	-10.0	-0.1
	H_2O	H_2O		1370.2	38.2	39.7	-1.5	1247.9	20.1	21.3	-1.2	1210.4	14.1	15.5	1.4
	H_2O	HF		1354.3	54.0	57.3	-3.3	1235.7	32.3	36.2	-3.9	1199.9	24.6	29.6	5.0
	H_2O	NH_3		1388.2	20.2	20.4	-0.2	1259.5	8.5	8.2	0.3	1218.8	5.7	5.7	0.0
	HF	H_2O		1341.8	66.6	68.8	-2.2	1223.9	44.1	47.6	-3.5	1192.0	32.5	36.1	3.6
	HF	HF		1325.1	83.2	86.4	-3.2	1212.0	56.0	62.5	-6.5	1182.1	42.4	50.2	7.8
	HF	NH_3		1360.6	47.8	49.5	-1.7	1237.3	30.7	34.5	-3.8	1202.7	21.8	26.3	4.5
	NH_3	H_2O		1393.3	15.1	15.9	-0.8	1265.7	2.3	2.5	-0.2	1226.0	-1.5	-1.3	0.2
	NH_3	HF		1377.6	30.7	33.5	-2.8	1255.0	13.0	17.4	-4.4	1217.6	6.9	12.8	5.9
	NH_3	NH_3		1410.8	-2.4	-3.4	1.0	1277.3	-9.3	-10.6	1.3	1234.6	-10.1	-11.1	-1.0
	H_2O		H_2O	1380.9	27.4	29.5	-2.1	1251.5	16.5	18.8	-2.3	1209.9	14.6	17.1	2.5
	H_2O		HF	1356.4	51.9	56.4	-4.5	1233.7	34.3	39.3	-5.0	1195.9	28.6	34.4	5.8
	H_2O		NH_3	1398.3	10.0	10.1	-0.1	1261.1	6.9	6.2	0.7	1216.4	8.1	7.7	-0.4
	HF		H_2O	1353.2	55.2	58.6	-3.4	1227.6	40.4	45.1	-4.7	1191.3	33.2	37.7	4.5
	HF		HF	1328.2	80.1	85.5	-5.4	1211.1	56.9	65.6	-8.7	1179.0	45.5	55.0	9.5
	HF		NH_3	1371.0	37.4	39.2	-1.8	1238.7	29.3	32.5	-3.2	1199.9	24.6	28.3	3.7
	NH_3		H_2O	1403.8	4.6	5.7	-1.1	1268.7	-0.7	0.0	-0.7	1224.9	-0.4	0.3	0.7
	NH_3		NH_3	1420.6	-12.3	-13.7	1.4	1279.1	-11.1	-12.6	1.5	1232.2	-7.7	-9.1	-1.4
		H_2O	H_2O	1378.6	29.8	30.8	-1.0	1253.1	14.9	15.9	-1.0	1215.4	9.1	9.6	0.5
		H_2O	HF	1353.1	55.2	57.7	-2.5	1235.2	32.8	36.4	-3.6	1202.0	22.5	26.9	4.4
		H_2O	NH_3	1397.5	10.9	11.4	-0.5	1264.7	3.3	3.3	0.0	1223.7	0.8	0.2	-0.6
		HF	H_2O	1362.3	46.1	48.4	-2.3	1240.8	27.2	30.8	-3.6	1205.3	19.2	23.7	4.5
		HF	HF	1335.8	72.5	75.3	-2.8	1222.9	45.1	51.3	-6.2	1192.0	32.5	41.0	8.5
		HF	NH_3	1381.9	26.5	29.0	-2.5	1253.6	14.4	18.2	-3.8	1215.2	9.3	14.3	5.0
		NH_3	H_2O	1397.3	11.0	11.5	-0.5	1265.8	2.2	2.8	-0.6	1224.5	0.0	-0.2	-0.2
		NH_3	HF	1372.5	35.8	38.4	-2.6	1249.9	18.1	23.3	-5.2	1213.6	10.9	17.1	6.2
		NH_3	NH_3	1414.8	-6.4	-7.9	1.5	1276.4	-8.4	-9.8	1.4	1232.5	-8.0	-9.6	-1.6
H_2O	HF	H_2O		1342.3	66.1	75.4	-9.3	1229.6	38.4	50.8	-12.4	1196.8	27.7	38.7	11.0
H_2O	HF	HF		1326.3	82.1	93.0	-10.9	1217.8	50.2	65.7	-15.5	1186.5	38.0	52.8	14.8
HF	H_2O	H_2O		1339.3	69.0	68.4	0.6	1231.6	36.4	42.7	-6.3	1197.8	26.7	33.5	6.8
HF	H_2O	HF		1323.8	84.6	86.0	-1.4	1220.7	47.3	57.6	-10.3	1188.2	36.3	47.6	11.3
HF	HF	H_2O		1320.1	88.2	97.5	-9.3	1215.1	52.9	69.0	-16.1	1186.1	38.4	54.1	15.7
HF	HF	HF		1302.7	105.7	115.1	-9.4	1202.3	65.7	83.9	-18.2	1174.9	49.6	68.2	18.6
HF	HF	NH_3		1339.8	68.6	78.2	-9.6	1230.5	37.5	55.9	-18.4	1199.1	25.4	44.3	18.9
H_2O	HF		H_2O	1353.8	54.5	65.2	-10.7	1233.4	34.6	48.3	-13.7	1196.7	27.8	40.3	12.5
H_2O	HF		HF	1332.2	76.2	92.1	-15.9	1219.0	49.0	68.8	-19.8	1186.0	38.5	57.6	19.1
HF	H_2O		H_2O	1353.7	54.6	58.2	-3.6	1238.5	29.5	40.2	-10.7	1200.4	24.1	35.1	11.0

HF	H_2O		HF	1332.2	76.1	85.1	-9.0	1224.5	43.5	60.7	-17.2	1189.7	34.8	52.4	17.6
HF	HF		H_2O	1334.4	73.9	87.3	-13.4	1221.4	46.6	66.5	-19.9	1188.4	36.1	55.7	19.6
HF	HF		HF	1311.2	97.1	114.2	-17.1	1205.8	62.2	87.0	-24.8	1175.9	48.6	73.0	24.4
HF	HF		NH_3	1351.3	57.1	67.9	-10.8	1231.8	36.2	53.9	-17.7	1196.3	28.2	46.3	18.1
H_2O		H_2O	H_2O	1375.6	32.8	37.4	-4.6	1251.1	16.9	19.1	-2.2	1213.8	10.7	12.2	1.5
H_2O		H_2O	HF	1353.3	55.0	64.3	-9.3	1236.2	31.8	39.6	-7.8	1202.8	21.7	29.5	7.8
H_2O		H_2O	NH_3	1393.1	15.2	18.0	-2.8	1263.2	4.8	6.5	-1.7	1222.8	1.7	2.8	1.1
H_2O		HF	H_2O	1359.8	48.6	55.0	-6.4	1239.9	28.1	34.0	-5.9	1204.5	20.0	26.3	6.3
H_2O		HF	HF	1336.8	71.6	81.9	-10.3	1224.5	43.5	54.5	-11.0	1192.7	31.8	43.6	11.8
H_2O		HF	NH_3	1377.5	30.8	35.6	-4.8	1251.7	16.3	21.4	-5.1	1213.6	10.9	16.9	6.0
H_2O		NH_3	H_2O	1393.9	14.4	18.1	-3.7	1264.7	3.3	6.0	-2.7	1223.4	1.1	2.4	1.3
H_2O		NH_3	HF	1372.4	35.9	45.0	-9.1	1250.7	17.3	26.5	-9.2	1214.6	9.9	19.7	9.8
H_2O		NH_3	NH_3	1409.5	-1.1	-1.3	0.2	1274.8	-6.8	-6.6	-0.2	1231.4	-6.9	-7.0	-0.1
HF		H_2O	H_2O	1357.4	51.0	59.5	-8.5	1238.5	29.5	37.3	-7.8	1204.1	20.4	27.6	7.2
HF		H_2O	HF	1334.7	73.6	86.4	-12.8	1223.2	44.8	57.8	-13.0	1193.2	31.3	44.9	13.6
HF		H_2O	NH_3	1374.8	33.6	40.1	-6.5	1249.4	18.6	24.7	-6.1	1212.0	12.5	18.2	5.7
HF		HF	H_2O	1340.5	67.9	77.1	-9.2	1226.4	41.6	52.2	-10.6	1194.1	30.4	41.7	11.3
HF		HF	HF	1316.5	91.9	104.0	-12.1	1209.8	58.2	72.7	-14.5	1181.9	42.6	59.0	16.4
HF		HF	NH_3	1358.7	49.6	57.7	-8.1	1237.9	30.1	39.6	-9.5	1203.1	21.4	32.3	10.9
HF		NH_3	H_2O	1376.6	31.7	40.2	-8.5	1252.6	15.4	24.2	-8.8	1214.7	9.8	17.8	8.0
HF		NH_3	HF	1354.6	53.7	67.1	-13.4	1239.6	28.4	44.7	-16.3	1207.0	17.5	35.1	17.6
HF		NH_3	NH_3	1392.6	15.7	20.8	-5.1	1262.1	5.9	11.6	-5.7	1222.1	2.4	8.4	6.0
NH_3		H_2O	H_2O	1392.9	15.4	18.0	-2.6	1262.9	5.1	6.8	-1.7	1221.2	3.3	3.4	0.1
NH_3		H_2O	HF	1369.8	38.5	44.9	-6.4	1247.0	21.0	27.3	-6.3	1210.3	14.2	20.7	6.5
NH_3		H_2O	NH_3	1410.0	-1.7	-1.4	-0.3	1274.3	-6.3	-5.8	-0.5	1230.2	-5.7	-6.0	-0.3
NH_3		HF	H_2O	1377.5	30.8	35.6	-4.8	1251.9	16.1	21.7	-5.6	1212.6	11.9	17.5	5.6
NH_3		HF	HF	1353.5	54.9	62.5	-7.6	1235.5	32.5	42.2	-9.7	1201.5	23.0	34.8	11.8
NH_3		HF	NH_3	1395.0	13.3	16.2	-2.9	1263.8	4.2	9.1	-4.9	1222.0	2.5	8.1	5.6
NH_3		NH_3	H_2O	1410.0	-1.6	-1.3	-0.3	1274.9	-6.9	-6.3	-0.6	1230.5	-6.0	-6.4	-0.4
NH_3		NH_3	HF	1388.0	20.4	25.6	-5.2	1260.1	7.9	14.2	-6.3	1221.3	3.2	10.9	7.7
NH_3		NH_3	NH_3	1426.5	-18.1	-20.7	2.6	1285.3	-17.3	-18.9	1.6	1238.6	-14.1	-15.8	-1.7
	H_2O	H_2O	H_2O	1362.4	46.0	50.0	-4.0	1241.5	26.5	28.0	-1.5	1204.3	20.2	21.1	0.9
	H_2O	H_2O	HF	1339.5	68.9	76.9	-8.0	1226.1	41.9	48.5	-6.6	1193.2	31.3	38.4	7.1
	H_2O	H_2O	NH_3	1379.6	28.8	30.6	-1.8	1252.5	15.5	15.4	0.1	1213.0	11.5	11.7	0.2
	H_2O	HF	H_2O	1347.8	60.5	67.6	-7.1	1231.1	36.9	42.9	-6.0	1196.0	28.5	35.2	6.7
	H_2O	HF	HF	1324.0	84.4	94.5	-10.1	1215.5	52.5	63.4	-10.9	1184.4	40.1	52.5	12.4
	H_2O	HF	NH_3	1365.7	42.6	48.2	-5.6	1242.8	25.2	30.3	-5.1	1205.3	19.2	25.8	6.6

	H_2O	NH_3	H_2O	1380.2	28.1	30.7	-2.6	1254.3	13.7	14.9	-1.2	1213.8	10.7	11.3	0.6
	H_2O	NH_3	HF	1358.0	50.4	57.6	-7.2	1240.3	27.7	35.4	-7.7	1204.7	19.8	28.6	8.8
	H_2O	NH_3	NH_3	1396.0	12.3	11.3	1.0	1264.2	3.8	2.3	1.5	1221.3	3.2	1.9	-1.3
	HF	H_2O	H_2O	1335.4	73.0	79.1	-6.1	1219.2	48.8	54.3	-5.5	1187.9	36.6	41.7	5.1
	HF	H_2O	HF	1311.9	96.5	106.0	-9.5	1203.7	64.3	74.8	-10.5	1176.5	48.0	59.0	11.0
	HF	H_2O	NH_3	1353.0	55.4	59.7	-4.3	1230.7	37.3	41.7	-4.4	1196.5	28.0	32.3	4.3
	HF	HF	H_2O	1320.2	88.2	96.7	-8.5	1208.6	59.4	69.2	-9.8	1179.3	45.2	55.8	10.6
	HF	HF	HF	1295.4	113.0	123.6	-10.6	1192.0	76.0	89.7	-13.7	1166.7	57.8	73.1	15.3
	HF	HF	NH_3	1338.3	70.0	77.3	-7.3	1220.5	47.5	56.6	-9.1	1188.6	35.9	46.4	10.5
	HF	NH_3	H_2O	1353.8	54.6	59.8	-5.2	1232.8	35.2	41.2	-6.0	1198.1	26.4	31.9	5.5
	HF	NH_3	HF	1331.1	77.3	86.7	-9.4	1219.3	48.7	61.7	-13.0	1189.8	34.7	49.2	14.5
	HF	NH_3	NH_3	1369.9	38.4	40.4	-2.0	1242.5	25.5	28.6	-3.1	1206.0	18.5	22.5	4.0
	NH_3	H_2O	H_2O	1385.3	23.0	26.2	-3.2	1260.3	7.7	9.2	-1.5	1220.6	3.9	4.3	0.4
	NH_3	H_2O	NH_3	1401.6	6.8	6.8	0.0	1270.7	-2.7	-3.4	0.7	1228.7	-4.2	-5.1	-0.9
	NH_3	HF	H_2O	1370.6	37.7	43.8	-6.1	1250.2	17.8	24.1	-6.3	1212.8	11.7	18.4	6.7
	NH_3	HF	NH_3	1387.4	20.9	24.4	-3.5	1261.0	7.0	11.5	-4.5	1221.3	3.2	9.0	5.8
	NH_3	NH_3	H_2O	1401.7	6.7	6.9	-0.2	1271.7	-3.7	-3.9	0.2	1229.2	-4.7	-5.5	-0.8
	NH_3	NH_3	HF	1379.6	28.7	33.8	-5.1	1258.3	9.7	16.6	-6.9	1221.3	3.2	11.8	8.6
	NH_3	NH_3	NH_3	1417.3	-9.0	-12.5	3.5	1281.1	-13.1	-16.5	3.4	1236.1	-11.6	-14.9	-3.3
H_2O	HF	H_2O	H_2O	1337.2	71.2	85.7	-14.5	1225.6	42.4	57.5	-15.1	1193.4	31.1	44.3	13.2
H_2O	HF	H_2O	HF	1316.5	91.9	112.6	-20.7	1211.7	56.3	78.0	-21.7	1183.4	41.1	61.6	20.5
H_2O	HF	HF	H_2O	1322.3	86.1	103.3	-17.2	1214.7	53.3	72.4	-19.1	1184.4	40.1	58.4	18.3
H_2O	HF	HF	HF	1300.6	107.8	130.2	-22.4	1200.4	67.6	92.9	-25.3	1173.7	50.8	75.7	24.9
HF	H_2O	H_2O	HF	1316.9	91.4	105.6	-14.2	1216.3	51.7	69.9	-18.2	1186.4	38.1	56.4	18.3
HF	H_2O	HF	H_2O	1322.2	86.2	96.3	-10.1	1219.3	48.7	64.3	-15.6	1187.5	37.0	53.2	16.2
HF	H_2O	HF	HF	1301.1	107.2	123.2	-16.0	1204.5	63.5	84.8	-21.3	1176.7	47.8	70.5	22.7
HF	HF	H_2O	H_2O	1318.0	90.4	107.8	-17.4	1213.6	54.4	75.7	-21.3	1185.0	39.5	59.7	20.2
HF	HF	H_2O	HF	1296.2	112.1	134.7	-22.6	1198.7	69.3	96.2	-26.9	1173.7	50.8	77.0	26.2
HF	HF	HF	H_2O	1301.6	106.7	125.4	-18.7	1201.7	66.3	90.6	-24.3	1174.9	49.6	73.8	24.2
HF	HF	HF	HF	1278.2	130.2	152.3	-22.1	1185.3	82.7	111.1	-28.4	1161.7	62.8	91.1	28.3
HF	HF	HF	NH_3	1318.8	89.6	106.0	-16.4	1213.0	55.0	78.0	-23.0	1183.7	40.8	64.4	23.6
HF	HF	NH_3	HF	1315.8	92.6	115.4	-22.8	1216.4	51.6	83.1	-31.5	1189.2	35.3	67.2	31.9
HF	HF	NH_3	NH_3	1352.1	56.2	69.1	-12.9	1237.1	30.9	50.0	-19.1	1203.6	20.9	40.5	19.6

[a]The N9 acidities were obtained from B3LYP/6-311+G(2d,p) single-point calculations on gas-phase B3LYP/6-31+G(d,p) geometries. [b]See Figure 6 for site notation. [c]Gas-phase single-point calculations. [d]PCM single-point calculations using a dielectric constant of 4.335. [e]PCM single-point calculations using a dielectric of 78.39. [f]Acidity is defined as the deprotonation enthalpy. [g]The effect of

XH on the acidity of uracil, which is calculated as difference in the acidity of free uracil and the uracil-XH complex. [h]The additive effects of two small molecules, which is calculated as the sum of the individual Δ_{XH}. [i]The deviation from additivity, which is calculated as Δ_{XH} minus Additivity.