Intra- and Intermolecular Interactions in Small Bioactive Molecules: Cooperative Features from Experimental and Theoretical Charge Density Analysis

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Supporting Information

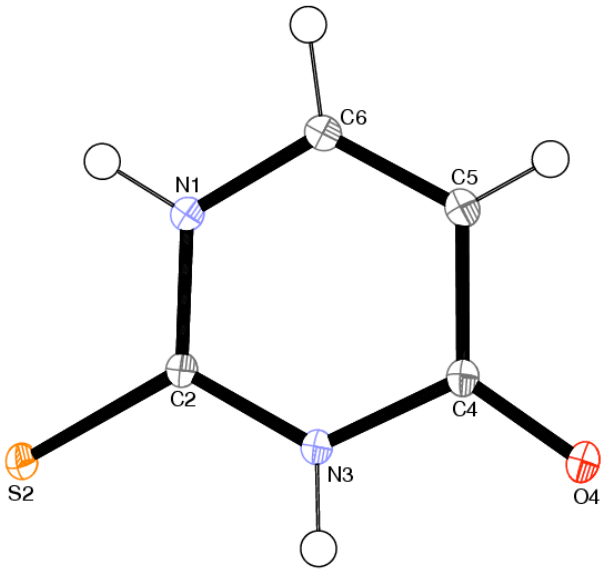

Figure S1. ORTEP view of 2-thiouracil at 90K with 50% ellipsoid probability (non-H atoms).

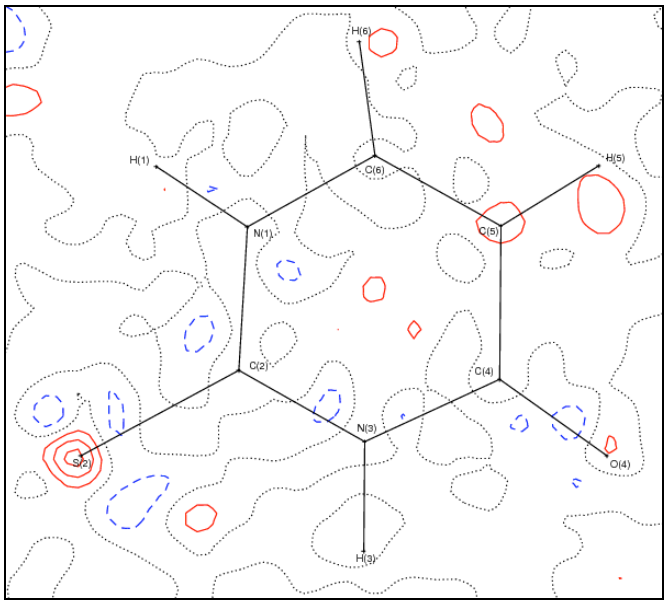

Figure S2. Residual density map in the molecular plane of 2-thiouracil. For all residual density and deformation density maps, the positive (solids red lines) and negative (broken blue lines) contours are with the interval of ± 0.1 eÅ^{-3}, black dotted lines are zero contours.

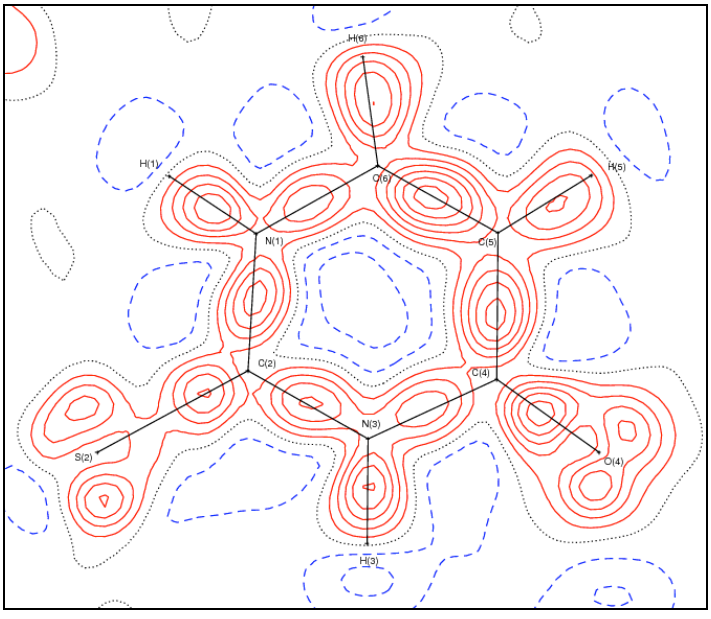

Figure S3. Dynamic deformation density map in the molecular plane of 2-thiouracil

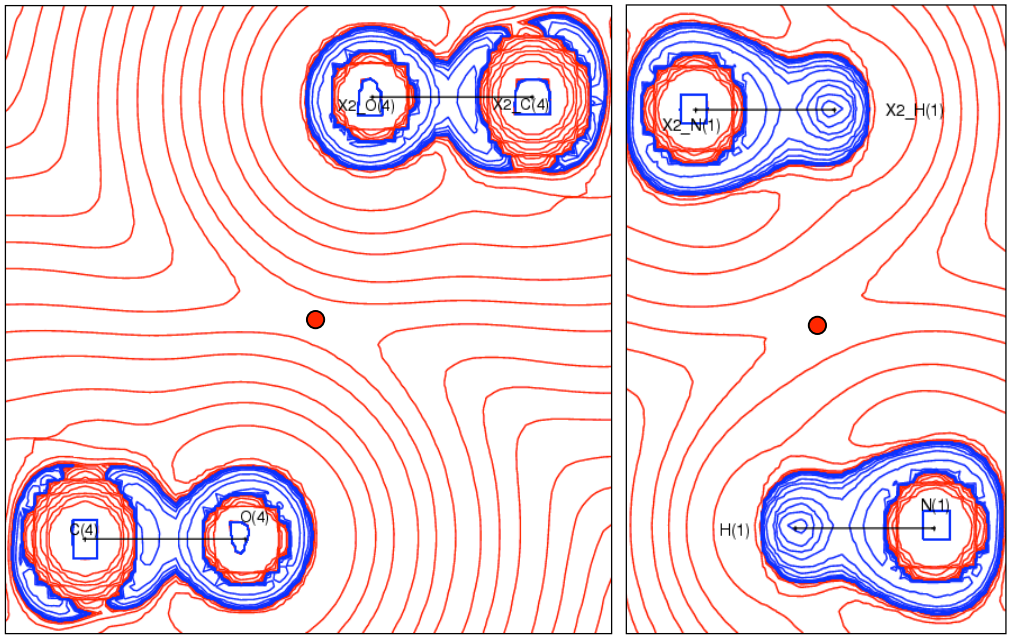

Figure S4. Laplacian [$\nabla^2\rho_b(r)$] distribution of the O···O and N···N intermolecular interaction.

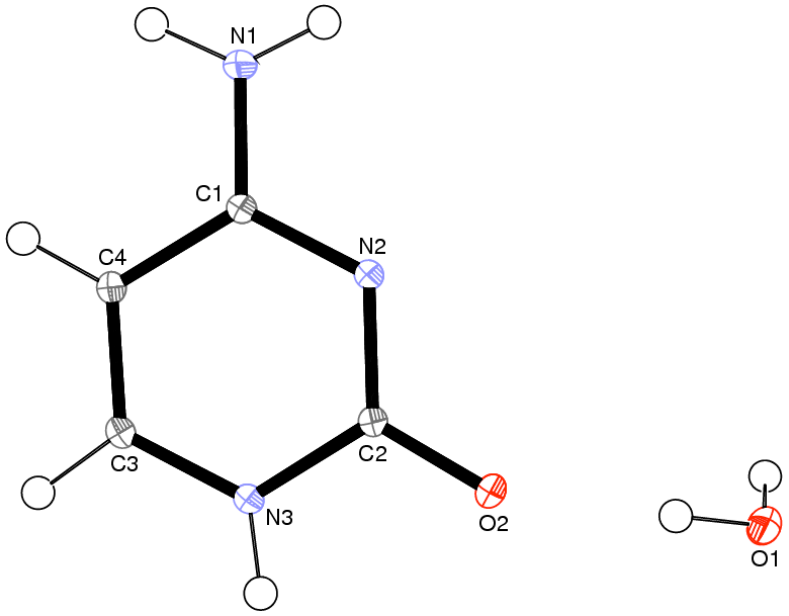

Figure S5. ORTEP view of cytosine monohydrate at 90K with 50% ellipsoid probability (non-H atoms).

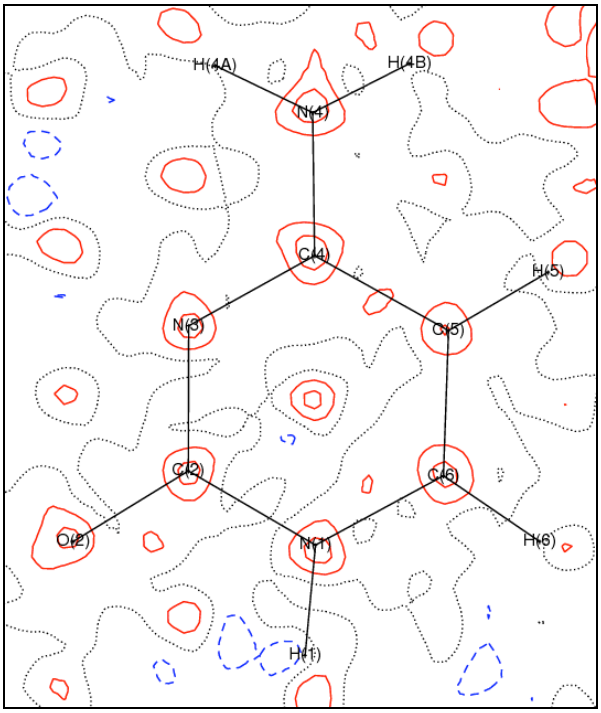

Figure S6. Residual density map in the molecular plane of cytosine monohydrate

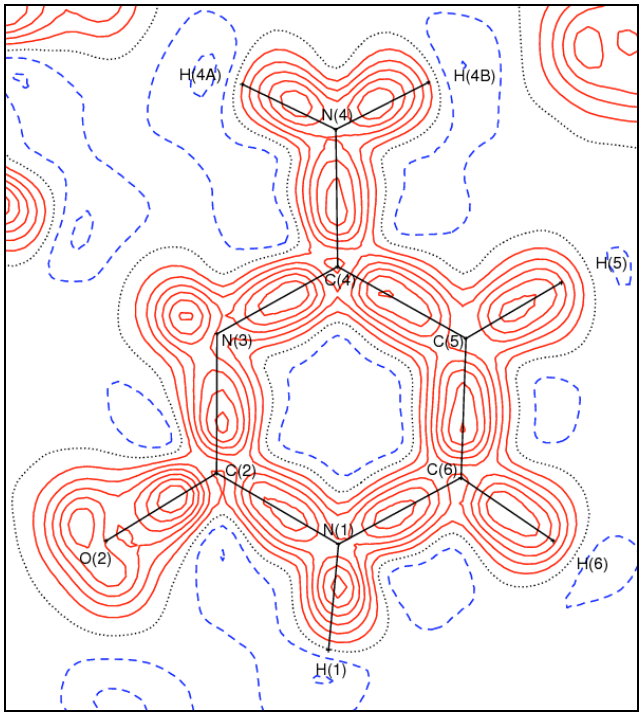

Figure S7. Dynamic deformation density map in the molecular plane of cytosine monohydrate

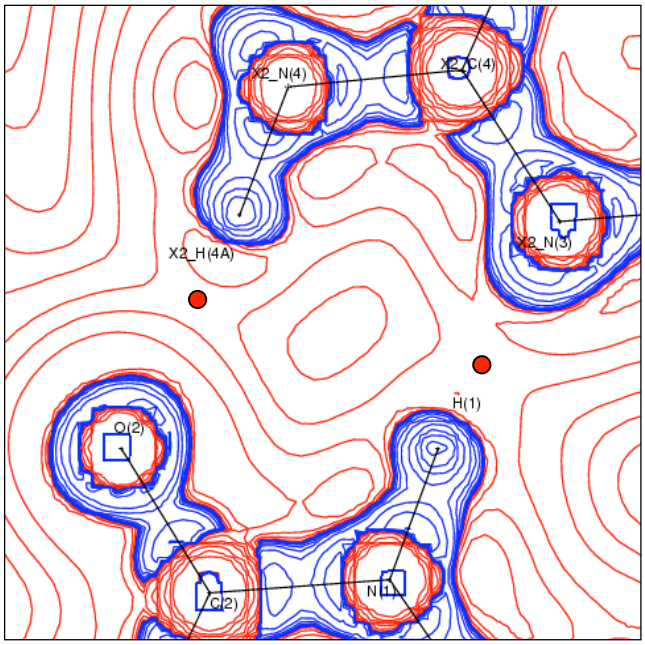

Figure S8. Laplacian [$\nabla^2\rho_b$(r)] distribution of the N–H···O and N–H···N hydrogen bonds.

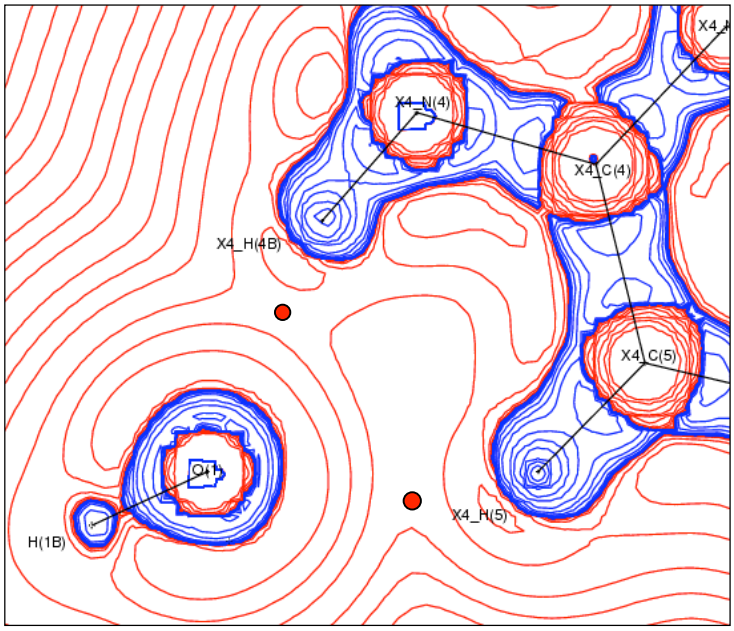

Figure S9. Laplacian [$\nabla^2\rho_b$(r)] distribution of the C–H···O and N–H···O hydrogen bonds.

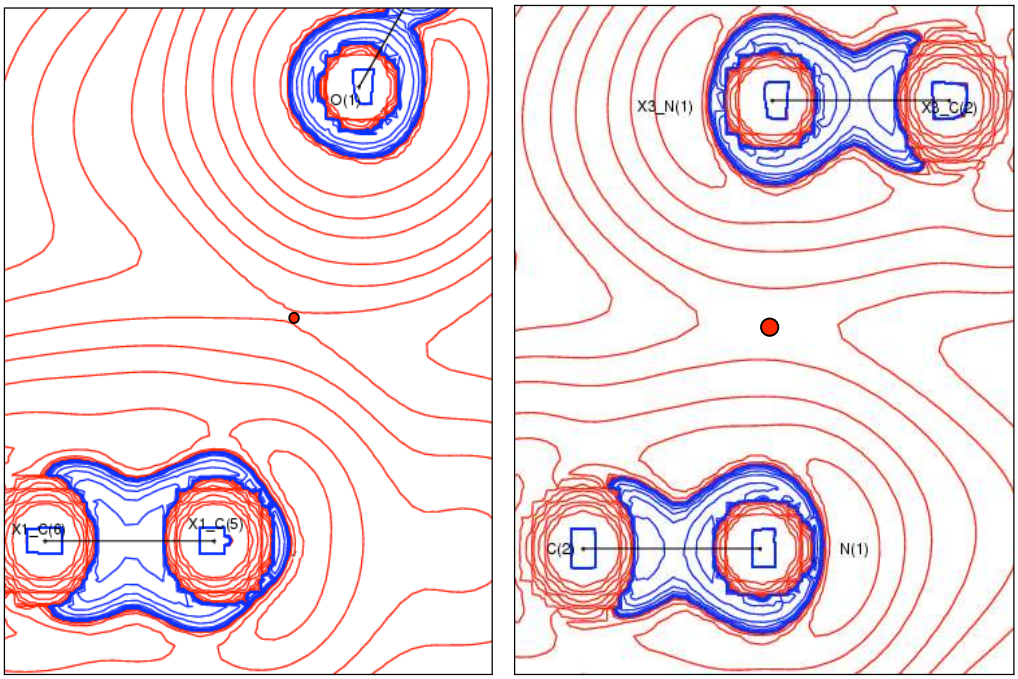

Figure S10. Laplacian [$\nabla^2\rho_b$(r)] distribution of the O···C and N···N interactions.

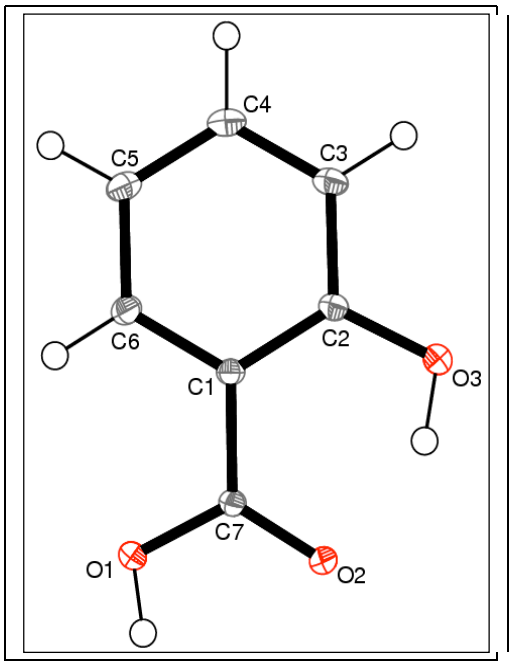

Figure S11. ORTEP view of salicylic acid at 90K with 50% ellipsoid probability (non- H atoms).

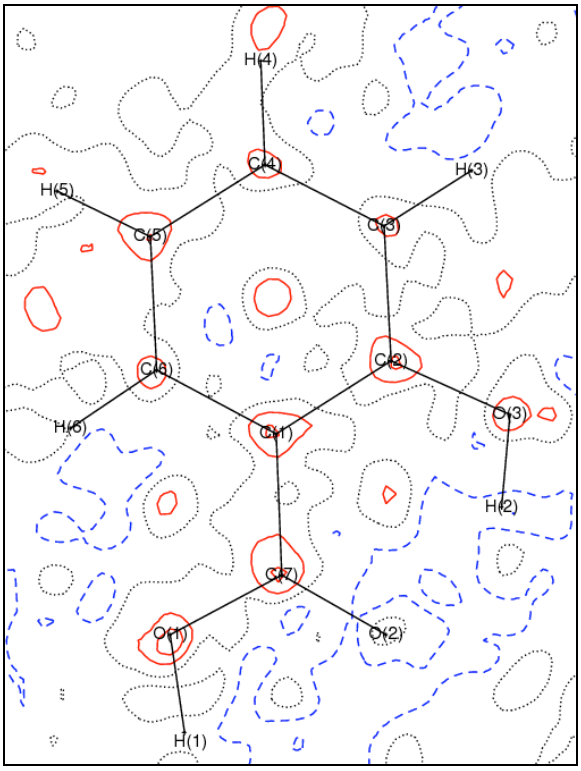

Figure S12. Residual density map in the molecular plane of salicylic acid

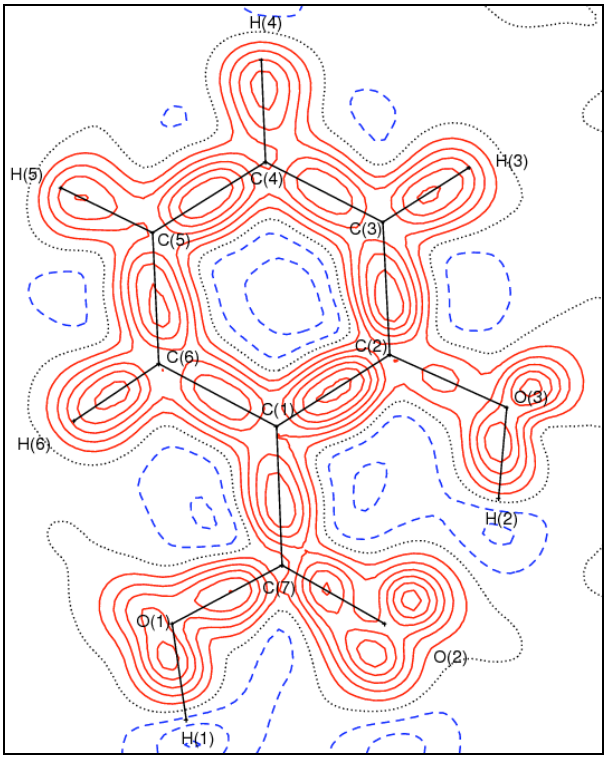

Figure S13. Dynamic deformation density map in the molecular plane of salicylic acid

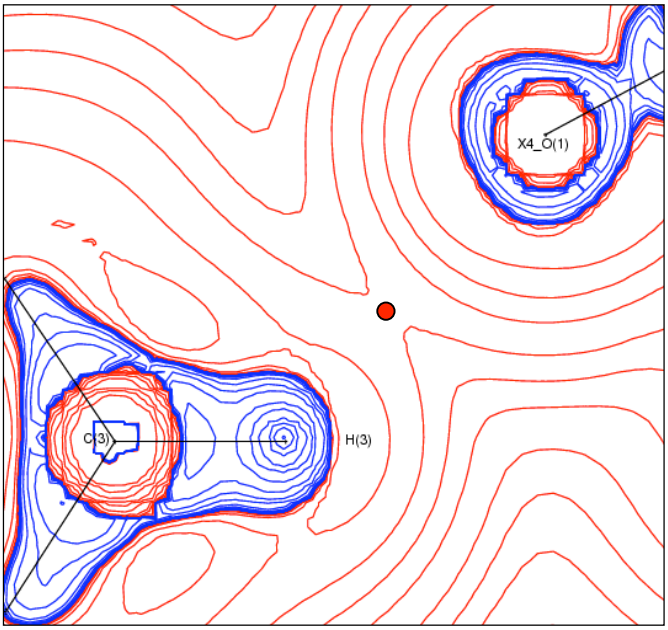

Figure S14. Laplacian [$\nabla^2\rho_b$(r)] distribution of a representative C–H···O hydrogen bond.

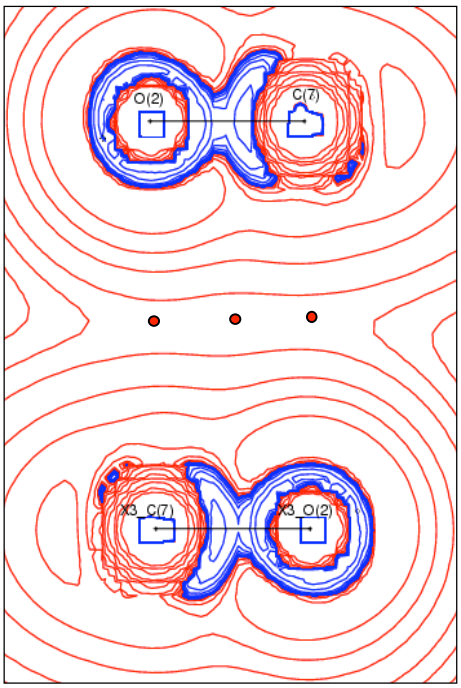

Figure S15. Laplacian [$\nabla^2\rho_b$(r)] distribution of O···C and O···O interactions.

Table S1. Radial parameters and atomic charges of 2-thiouracil (Theoretical):

atoms	κ	κ'	q
S(2)	0.985	0.911	-0.372
O(4)	0.987	0.957	-0.23
N(1)	0.998	0.829	-0.101
N(3)	0.998	0.829	-0.117
C(2)	1.003	0.855	-0.075
C(4)	1.003	0.855	0.014
C(6)	1.003	0.855	-0.015
C(5)	1.003	0.855	-0.055
H(6)	1.2	1.2	0.192
H(5)	1.2	1.2	0.187
H(1)	1.2	1.2	0.284
H(3)	1.2	1.2	0.289

Table S2. Multipole population coefficients of 2-thiouracil (Theoretical):

atom	P_v	P_{00}	P_{11}	P_{1-1}	P_{10}
S(2)	6.37(1)	0.00(0)	0.00(0)	0.02(0)	-0.10(0)
O(4)	6.23(0)	0.00(0)	0.00(0)	0.00(0)	-0.12(0)
N(1)	5.10(1)	0.00(0)	0.01(0)	-0.03(0)	0.06(0)
N(3)	5.12(1)	0.00(0)	0.00(0)	-0.03(0)	0.03(0)
C(2)	4.08(1)	0.00(0)	-0.01(0)	-0.09(0)	-0.05(0)
C(4)	3.99(1)	0.00(0)	0.01(0)	-0.07(0)	0.10(0)
C(6)	4.02(1)	0.00(0)	0.00(0)	0.10(0)	0.02(1)
C(5)	4.06(1)	0.00(0)	0.02(0)	0.03(1)	0.02(0)
H(6)	0.81(1)	0.00(0)	0.00(0)	0.00(0)	0.15(0)
H(5)	0.81(0)	0.00(0)	0.00(0)	0.00(0)	0.15(0)
H(1)	0.72(0)	0.00(0)	0.00(0)	0.00(0)	0.12(0)
H(3)	0.71(0)	0.00(0)	0.00(0)	0.00(0)	0.13(0)

atom	P_{20}	P_{21}	P_{2-1}	P_{22}	P_{2-2}
S(2)	-0.21(0)	0.02(0)	0.02(0)	-0.08(0)	-0.01(0)
O(4)	-0.05(0)	0.01(0)	-0.01(0)	-0.10(0)	0.00(0)
N(1)	0.05(0)	0.00(0)	0.01(0)	0.01(0)	0.00(0)
N(3)	0.06(0)	0.00(0)	0.01(0)	0.00(0)	0.01(0)
C(2)	0.11(0)	0.00(0)	0.05(0)	-0.23(0)	-0.01(0)
C(4)	0.26(0)	0.00(0)	0.07(0)	-0.19(0)	-0.01(0)
C(6)	0.18(0)	-0.02(0)	-0.09(0)	-0.19(0)	-0.01(0)
C(5)	0.13(0)	0.01(0)	-0.03(0)	-0.14(0)	0.00(0)

atom	P_{30}	P_{31}	P_{3-1}	P_{32}	P_{3-2}	P_{33}	P_{3-3}
S(2)	0.10(0)	-0.01(0)	-0.01(0)	0.01(0)	0.00(0)	0.02(0)	0.00(0)
O(4)	0.03(0)	-0.01(0)	0.01(0)	0.01(0)	0.00(0)	0.00(0)	-0.01(0)
N(1)	0.25(0)	-0.01(0)	0.02(0)	0.14(0)	-0.02(0)	0.01(0)	0.00(0)
N(3)	0.23(0)	0.00(0)	0.02(0)	0.15(0)	0.00(0)	0.01(0)	0.02(0)
C(2)	0.30(1)	0.01(0)	0.00(1)	0.19(1)	0.00(1)	0.00(0)	-0.06(0)
C(4)	0.33(1)	0.01(0)	-0.02(1)	0.25(1)	0.00(1)	0.00(0)	-0.03(0)
C(6)	0.31(1)	-0.03(0)	0.05(1)	0.18(1)	0.03(0)	-0.04(0)	0.09(0)
C(5)	0.26(1)	-0.01(0)	-0.01(1)	0.16(1)	0.01(1)	0.00(0)	0.02(1)

atom	P_{40}	P_{41}	P_{4-1}	P_{42}	P_{4-2}	P_{43}	P_{4-3}	P_{44}	P_{4-4}
S(2)	0.04(0)	0.00(0)	-0.01(0)	-0.01(0)	0.00(0)	0.00(0)	-0.01(0)	0.01(0)	0.01(0)
O(4)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
N(1)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
N(3)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(2)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(4)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(6)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(5)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)

Table S3. Radial parameters and atomic charges of cytosine monohydrate (Theoretical):

atoms	κ	κ'	q
O(1)	0.981	1.057	-0.467
O(2)	0.975	1.218	-0.422
N(1)	1.004	1.039	0.09
N(3)	0.993	0.762	0.034
N(4)	1.004	1.039	-0.024
C(2)	0.988	0.846	-0.176
C(4)	0.988	0.846	-0.267
C(5)	0.988	0.846	-0.113
C(6)	0.988	0.846	-0.192
H(1)	1.2	1.2	0.241
H(1A)	1.2	1.2	0.215
H(1B)	1.2	1.2	0.219
H(4A)	1.2	1.2	0.187
H(4B)	1.2	1.2	0.186
H(5)	1.2	1.2	0.253
H(6)	1.2	1.2	0.237

Table S4. Multipole population coefficients of cytosine monohydrate (Theoretical):

atom	P_v	P_{00}	P_{11}	P_{1-1}	P_{10}
O(1)	6.47(0)	0.00(0)	0.01(0)	-0.06(0)	-0.04(0)
O(2)	6.42(1)	0.00(0)	0.00(0)	0.00(0)	-0.09(0)
N(1)	4.91(1)	0.00(0)	0.01(0)	-0.01(0)	0.05(0)
N(3)	4.97(1)	0.00(0)	0.00(1)	-0.16(1)	-0.12(1)
N(4)	5.02(1)	0.00(0)	0.00(0)	0.05(0)	0.03(0)
C(2)	4.18(1)	0.00(0)	-0.01(1)	0.03(1)	-0.05(1)
C(4)	4.27(2)	0.00(0)	-0.01(1)	0.02(1)	-0.03(1)
C(5)	4.11(2)	0.00(0)	0.02(1)	0.05(1)	0.05(1)
C(6)	4.19(2)	0.00(0)	0.02(1)	0.02(1)	0.00(1)
H(1)	0.76(1)	0.00(0)	0.00(0)	0.00(0)	0.14(0)
H(1A)	0.78(0)	0.00(0)	0.00(0)	0.00(0)	0.10(0)
H(1B)	0.78(0)	0.00(0)	0.00(0)	0.00(0)	0.14(0)
H(4A)	0.81(1)	0.00(0)	0.00(0)	0.00(0)	0.15(0)
H(4B)	0.81(0)	0.00(0)	0.00(0)	0.00(0)	0.16(0)
H(5)	0.75(1)	0.00(0)	0.00(0)	0.00(0)	0.09(0)
H(6)	0.76(1)	0.00(0)	0.00(0)	0.00(0)	0.13(0)

atom	P_{20}	P_{21}	P_{2-1}	P_{22}	P_{2-2}
O(1)	-0.04(0)	0.00(0)	0.03(0)	0.07(0)	0.00(0)
O(2)	-0.07(0)	0.00(0)	0.00(0)	0.02(0)	0.04(0)
N(1)	0.02(0)	0.00(0)	0.00(0)	0.04(0)	0.00(0)
N(3)	0.01(1)	0.00(1)	0.10(1)	-0.10(1)	0.01(1)
N(4)	-0.01(0)	0.01(0)	-0.03(0)	0.03(0)	0.01(0)
C(2)	0.20(1)	-0.01(0)	-0.07(1)	-0.21(1)	-0.01(1)
C(4)	0.15(1)	0.00(1)	-0.01(1)	-0.26(1)	0.00(1)
C(5)	0.15(1)	-0.01(1)	-0.06(1)	-0.13(1)	0.01(1)
C(6)	0.18(1)	-0.03(1)	-0.06(1)	-0.23(1)	-0.02(1)

atom	P_{30}	P_{31}	P_{3-1}	P_{32}	P_{3-2}	P_{33}	P_{3-3}
O(1)	0.08(0)	0.00(0)	-0.03(0)	0.03(0)	-0.01(0)	0.00(0)	-0.04(0)
O(2)	0.05(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.01(0)	-0.01(0)
N(1)	0.16(0)	0.00(0)	0.03(0)	0.09(0)	0.01(0)	0.00(0)	0.00(0)
N(3)	0.07(1)	-0.01(1)	0.04(1)	0.04(1)	-0.01(1)	-0.02(1)	-0.01(1)
N(4)	0.12(0)	0.01(0)	0.03(0)	0.09(0)	0.01(0)	-0.02(0)	0.01(0)
C(2)	0.42(1)	-0.01(1)	0.05(1)	0.26(1)	0.01(1)	0.02(1)	0.07(1)
C(4)	0.43(1)	0.03(1)	-0.04(1)	0.33(1)	0.02(1)	0.01(1)	0.00(1)
C(5)	0.29(1)	0.00(1)	0.05(1)	0.19(1)	0.00(1)	0.01(1)	0.06(1)
C(6)	0.39(1)	-0.02(1)	0.01(1)	0.20(1)	-0.01(1)	-0.01(1)	0.04(1)

atom	P_{40}	P_{41}	P_{4-1}	P_{42}	P_{4-2}	P_{43}	P_{4-3}	P_{44}	P_{4-4}
O(1)	0.05(0)	0.00(0)	0.01(0)	0.00(0)	0.00(0)	0.01(0)	0.02(0)	0.02(0)	0.00(0)
O(2)	0.02(0)	-0.01(0)	0.00(0)	-0.01(0)	0.00(0)	-0.01(0)	0.01(0)	0.00(0)	0.01(0)
N(1)	0.04(1)	0.02(0)	-0.01(1)	0.00(1)	0.01(1)	0.00(0)	-0.02(1)	0.01(0)	0.00(0)
N(3)	0.00(1)	-0.03(1)	-0.03(1)	0.01(1)	0.02(1)	-0.02(1)	0.02(1)	0.04(1)	0.01(1)
N(4)	0.00(1)	0.01(0)	0.02(0)	-0.01(0)	-0.01(0)	0.03(0)	0.03(0)	0.02(0)	-0.01(0)
C(2)	-0.03(1)	0.01(1)	0.06(1)	-0.07(1)	0.01(1)	0.01(1)	0.01(1)	0.02(1)	0.00(1)
C(4)	0.04(1)	0.03(1)	-0.01(1)	0.00(1)	-0.01(1)	0.02(1)	0.00(1)	0.04(1)	-0.03(1)
C(5)	0.11(1)	0.00(1)	0.02(1)	0.00(1)	0.01(1)	0.03(1)	0.05(1)	0.02(1)	-0.03(1)
C(6)	0.05(1)	0.01(1)	-0.03(1)	0.01(1)	0.02(1)	0.00(1)	-0.07(1)	0.02(1)	-0.02(1)

Table S5. Radial parameters and atomic charges of salicylic acid (Theoretical):

atoms	κ	κ'	q
O(1)	0.992	1.210	-0.207
O(3)	0.992	1.210	-0.268
O(2)	0.988	0.960	-0.225
C(1)	1.000	0.863	0.11
C(3)	1.000	0.863	-0.025
C(6)	1.000	0.863	-0.196
C(2)	1.000	0.863	0.003
C(5)	1.000	0.863	-0.083
C(4)	1.000	0.863	-0.065
C(7)	0.994	0.829	-0.096
H(6)	1.2	1.2	0.159
H(3)	1.2	1.2	0.13
H(5)	1.2	1.2	0.122
H(4)	1.2	1.2	0.158
H(2)	1.2	1.2	0.221
H(1)	1.2	1.2	0.262

Table S6. Multipole population coefficients of salicylic acid (Theoretical):

atom	P_v	P_{00}	P_{11}	P_{1-1}	P_{10}
O(1)	6.21(1)	0.00(0)	0.00(0)	-0.07(0)	-0.02(0)
O(3)	6.27(1)	0.00(0)	0.00(0)	-0.08(0)	-0.03(0)
O(2)	6.23(1)	0.00(0)	-0.01(0)	0.00(0)	-0.14(0)
C(1)	3.89(1)	0.00(0)	0.03(0)	0.04(1)	0.07(1)
C(3)	4.03(1)	0.00(0)	-0.01(0)	0.02(1)	0.01(1)
C(6)	4.20(1)	0.00(0)	0.01(0)	0.02(1)	0.01(1)
C(2)	4.00(1)	0.00(0)	-0.01(0)	-0.01(1)	-0.11(0)
C(5)	4.08(1)	0.00(0)	0.00(0)	-0.01(1)	-0.02(1)
C(4)	4.07(1)	0.00(0)	0.01(0)	0.02(1)	0.02(1)
C(7)	4.10(2)	0.00(0)	-0.03(0)	-0.05(0)	0.10(1)
H(6)	0.84(1)	0.00(0)	0.00(0)	0.00(0)	0.10(0)
H(3)	0.87(1)	0.00(0)	0.00(0)	0.00(0)	0.15(0)
H(5)	0.88(1)	0.00(0)	0.00(0)	0.00(0)	0.14(0)
H(4)	0.84(1)	0.00(0)	0.00(0)	0.00(0)	0.14(0)
H(2)	0.78(0)	0.00(0)	0.00(0)	0.00(0)	0.12(0)
H(1)	0.74(0)	0.00(0)	0.00(0)	0.00(0)	0.13(0)

atom	P_{20}	P_{21}	P_{2-1}	P_{22}	P_{2-2}
O(1)	-0.01(0)	0.01(0)	0.05(0)	0.04(0)	0.00(0)
O(3)	-0.02(0)	0.00(0)	0.06(0)	0.06(0)	0.00(0)
O(2)	-0.07(0)	0.01(0)	0.00(0)	-0.09(0)	-0.01(0)
C(1)	0.10(1)	0.01(0)	-0.03(0)	-0.12(0)	0.00(0)
C(3)	0.10(0)	-0.02(0)	-0.02(0)	-0.15(0)	0.01(0)
C(6)	0.13(0)	0.00(0)	-0.03(0)	-0.22(0)	0.01(0)
C(2)	0.03(0)	0.00(0)	-0.01(0)	-0.23(0)	-0.02(0)
C(5)	0.12(0)	0.00(0)	0.00(0)	-0.18(0)	0.00(0)
C(4)	0.13(1)	-0.01(0)	-0.01(0)	-0.22(0)	0.02(0)
C(7)	0.27(1)	-0.01(0)	0.07(0)	-0.26(1)	0.00(0)

atom	P_{30}	P_{31}	P_{3-1}	P_{32}	P_{3-2}	P_{33}	P_{3-3}
O(1)	0.05(0)	0.00(0)	-0.01(0)	0.02(0)	0.00(0)	0.00(0)	-0.01(0)
O(3)	0.05(0)	0.00(0)	-0.02(0)	0.03(0)	0.00(0)	0.00(0)	-0.02(0)
O(2)	0.04(0)	-0.01(0)	-0.01(0)	0.02(0)	0.00(0)	0.01(0)	0.01(0)
C(1)	0.18(1)	-0.02(1)	-0.01(1)	0.18(1)	0.00(1)	0.02(0)	-0.02(1)
C(3)	0.23(1)	-0.01(0)	0.02(1)	0.17(1)	-0.01(0)	0.01(0)	0.03(1)
C(6)	0.30(1)	-0.03(0)	0.00(1)	0.18(1)	0.01(1)	0.01(0)	-0.01(1)
C(2)	0.35(1)	-0.02(0)	-0.04(1)	0.23(1)	0.02(0)	-0.01(0)	0.00(1)
C(5)	0.26(1)	-0.01(0)	-0.03(1)	0.19(1)	-0.02(1)	0.02(0)	0.00(0)
C(4)	0.30(1)	0.03(0)	0.01(1)	0.16(1)	0.02(0)	0.00(0)	0.01(1)
C(7)	0.45(1)	0.01(1)	-0.01(1)	0.29(1)	-0.03(1)	0.00(0)	0.02(0)

atom	P_{40}	P_{41}	P_{4-1}	P_{42}	P_{4-2}	P_{43}	P_{4-3}	P_{44}	P_{4-4}
O(1)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
O(3)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
O(2)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(1)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(3)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(6)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(2)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(5)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(4)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)
C(7)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)	0.00(0)