Studies on Intermolecular Complex Formation. I. Between Nucleotide Bases and Organic Compounds

Chihiro TAMURA, Noriko SAKURAI, and Sadao SATO

The Central Research Laboratories of Sankyo Co., Ltd., Hiromachi, Shinagawa-ku, Tokyo

(Received October 30, 1970)

The present investigation was focussed on a survey of the chemical compounds which are capable of binding with nucleotide bases. X-Ray powder patterns show that adenine and cytosine have a strong tendency to interact with many organic compounds having a carboxyl group and cyclic alternant CONH groups. A few compounds bind with thymine and uracil.

In view of the structure and function of DNA, many single crystal analyses of the complexes between the nucleotide bases have been analyzed.[1-7] Several types of base-pairing were found, and in these complexes the principal binding force is due to complementary hydrogen bonds. We had expected that complexes exist not only between the nucleotide bases themselves but also between nucleotide bases and other organic compounds having some characteristic structure. By infrared spectrum, Kyogoku *et al.* studied some biologically active compounds which interact with nucleotide bases in solution.[8]

The X-ray powder method was applied in surveying these compounds with respect to their ability to form complexes with nucleotide bases. A large number of combinations was found to give rise to a change in diffraction patterns which might indicate the formation of complex. Some of them were obtained in the form of single crystal and we succeeded in determining their crystal structures.[9,10] New types of intermolecular hydrogen bonding were found, the details of which will be published elsewhere. In the present paper we will describe the results of the survey and discuss the structural characteristics of the molecules which can form the complexes.

Experimental

The experimental procedure was as follows: equivalent moles (*ca.* 100 mg) of organic substance and the base were added to 70% aqueous ethanol (*ca.* 15 cc). The mixture was warmed on a water-bath until dissolution was complete and then allowed to stand for several days in a refrigerator. A glass holder with a depth of 0.2 mm was filled with crystalline material thus obtained, and X-ray diffractions were recorded up to $2\sin\theta=50°$ with a Rigakudenki model D6C diffractometer. Spacings of diffraction peaks are listed in Table 4, the height of the maximum peaks being normalized to one hundred.

The formation of new crystalline species was verified by comparing their diffraction patterns with those of components. An example of such comparison is shown in Fig. 1. All component samples were recrystallized by use of the same solvent in order to avoid an erroneous conclusion due to polymorphism of the components. The mass and infrared spectra of such crystals were sometimes useful in confirming the formation of new complexes. The stability of each crystal was examined by taking diffraction patterns of the same sample at intervals of several hours. Any changes in these patterns indicate that the substance is unstable at room temperature and humidity. Subsequently such samples were kept during measurements at a low temperature and at the same humidity as that in the refrigerator.

Some of the complexes showed only a small number of new peak superimposed over those of the diffraction patterns of the components. In such cases, the diffraction patterns were recorded repeatedly more than three times to confirm their reproducibility.

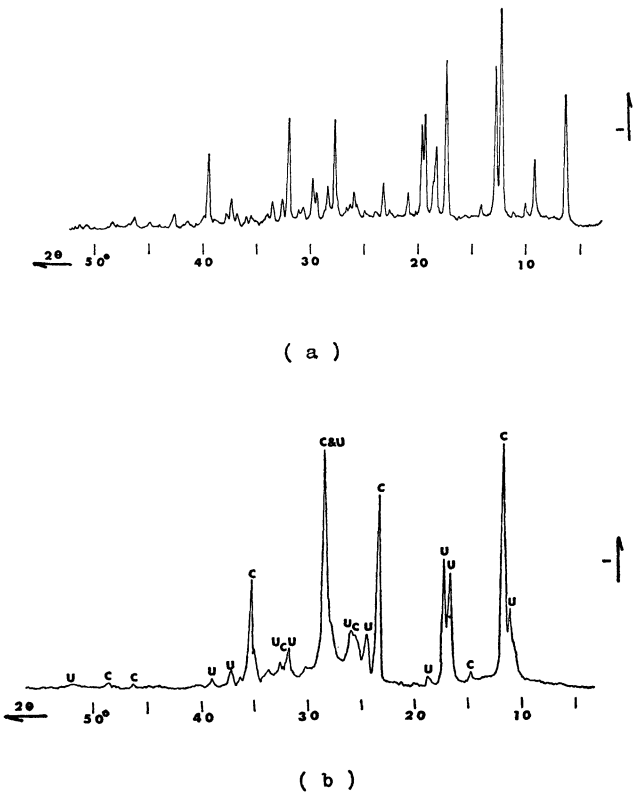


Fig. 1. X-ray powder pattern of the complex of uracil-cytosine (a), the pattern of a mechanical mixture of uracil (U) and cytosine (C), the original components, (b). $\lambda=1.5418$.

1) F. S. Mathews and A. Rich, *J. Mol. Biol.*, **8**, 89 (1964).
2) L. Katz, K. Tomita, and A. Rich, *ibid.*, **13**, 340 (1969).
3) A. E. V. Hashemeyer and H. M. Sobell, *Acta Cryst.*, **18**, 525 (1965).
4) E. J. O'Brien, *ibid.*, **23**, 92 (1967).
5) H. M. Sobell, K. Tomita, and A. Rich, *Proc. Natl. Acad. Sci. U.S.*, **40**, 885 (1963).
6) A. E. Hashemeyer and H. M. Sobell, *Nature*, **202**, 969 (1964).
7) K. Hoogsteen, *Acta Cryst.*, **12**, 822 (1959); *ibid.*, **16**, 907 (1963).
8) Y. Kyogoku, R. C. Lord, and A. Rich, *Nature*, **218**, 69 (1968).
9) C. Tamura, N. Sakurai, and S. Sato, The Proceeding of the Conference of Chemical Society of Japan, p. 423 (1970).
10) *Ibid.*, p. 424 (1970).

Results and Discussion

The results of the experiments, in part, are shown in Tables 1 and 2. A + sign denotes the formation of a new crystalline species and a 0 designates that no change for a pair was observed under these conditions. The sign ± indicates that only a few new diffraction peaks were observed in addition to the original peaks. Some of the new crystalline species were established as being due to complex formation by means of single crystal analysis, and some were suggested to be complexes by infrared spectra or mass spectra. Therefore, it

TABLE 1. INTERMOLECULAR COMPLEX FORMATION BETWEEN SOME ACIDS AND NUCLEOTIDE BASES
With thymine and uracil all are not interactive

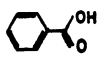
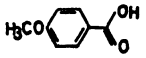
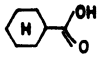
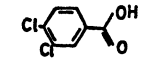
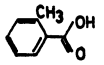
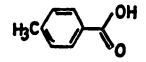
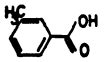
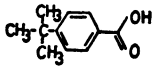
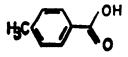
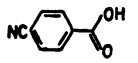
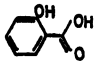
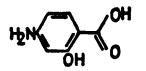
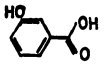
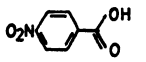
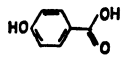
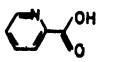
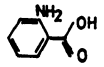
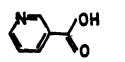
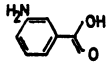
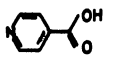
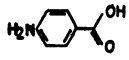
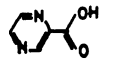
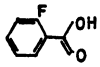
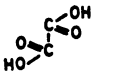
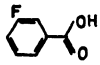
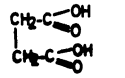
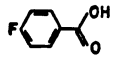
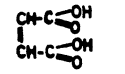
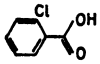
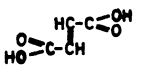
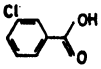
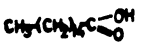
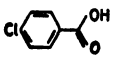
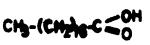
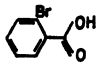
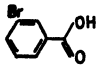
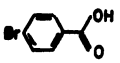
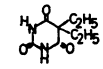
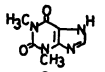
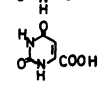
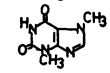
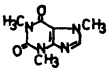
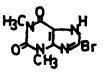
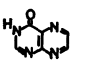
	Adenine	Cytosine		Adenine	Cytosine
 benzoic acid	+	+	 anisic acid	+	0
 cyclohexanecarboxylic acid	+	+	 3,4-dichlorobenzoic acid	+	+
 *o*-tuluic acid	+	+	 *p*-toluic acid	+	0
 *m*-toluic acid	+	+	 *p-tert*-butylbenzoic acid	+	±
 *p*-toluic acid	+	0	 *p*-cyanobenzoic acid	+	+
 salicylic acid	+	+	 *p*-aminosalicylic acid	+	+
 *m*-hydroxybenzoic acid	+	+	 *p*-nitrobenzoic acid	+	+
 *p*-hydroxybenzoic acid	+	+	 picolinic acid	+	+
 anthranilic acid	+	0	 nicotinic acid	+	+
 *m*-aminobenzoic acid	+	0	 isonicotinic acid	0	+
 *p*-aminobenzoic acid	+	0	 pyradinic acid	+	+
 *o*-fluorobenzoic acid	+	+	 oxalic acid	+	+
 *m*-fluorobenzoic acid	+	+	 succinic acid	+	+
 *p*-fluorobenzoic acid	+	+	 maleic acid	+	+
 *o*-chlorobenzoic acid	+	+	 fumaric acid	+	+
 *m*-chlorobenzoic acid	+	+	 palmitic acid	±	0
 *p*-chlorobenzoic acid	0	±	 stearic acid	±	0
 *o*-bromobenzoic acid	+	+			
 *m*-bromobenzoic acid	+	+			
 *p*-bromobenzoic acid	0	0			

Table 2. Intermolecular complex formation between nucleotide bases and related compounds of nucleotide bases

With thymine and uracil all are not interactive

	adenine	cytosine		adenine	cytosine
 uracil	±	+	 benzoylene urea	+	0
 thymine	+	0	 phthalazine-1,4-dione	0	0
 5-bromouracil	+	+	 2-3-dihydroxyquinoxaline	0	0
 5-nitrouracil	+	+	 1-(2*H*)-phthalazinone	+	+
 4-amino-1,3-dimethyl-uracil	0	0	 4-ketobenzotriazine	0	0
 alloxane	+	+	 isatonicanhydride	0	0
 barbituric acid	+	+	 phthalimide	0	0
 barbital	+	0	 3-indazolinone	0	0
 cyanuric acid	+	0	 theophylline	+	+
 orotic acid	+	+	 theobromine	+	0
 4,6-dihydroxy-2-mercapto-pyrimidine	+	+	 caffeine	0	0
 2-amino-4-hydroxy-6-methylpyrimidine	0	+	 8-bromotheophylline	0	0
 2-amino-4-hydroxy-5,6-dimethylpyrimidine	+	0	 4-hydroxypteridine	0	+
 3,6-dioxohexahydro-1,2,4,5-tetrazine	0	0			

seems most probable to assume that the new crystalline-species correspond to those of the complexes, but not another modification of the components. Table 3 shows the number of substances forming complexes and the total number examined; they can be classified into six categories. It has been observed that adenine and cytosine form complexes with many organic compounds, while thymine and uracil form hardly any such complexes with those examined. Guanine was not included because of its poor solubility. The spacings listed in Table 4 are for the complexes and their components.

Table 3. Complex-formation ability of organic compounds with adenine and cytosine

number of substances forming complexes / total number of substances examined

	Category	For adenine		For cytosine	
1	Containing -COOH	33/36	91.8%	28/36	77.8%
2	Containing $-\underset{\overset{\oplus}{NH_3}}{\underset{|}{CH}}-COO^{\ominus}$	0/18	0.0	0/18	0.0
3	Containing $-CONH_2$	1/17	5.9	0/17	0.0
4	Linear molecules containing CO & NH	0/10	0.0	0/10	0.0
5	Cyclic molecules containing CO & NH	6/39	15.4	5/39	12.8
6	Cyclic molecules containing -CONHCONH-	11/12	91.6	5/12	41.6

Carboxylic Acids. Table 3 shows that 92% of the carboxylic acids examined can bind with adenine and 78% with cytosine. Even long chain fatty acids, which are structurally different from the planar molecule of adenine, form the complexes as shown in Table 1. The structure of single crystal analysis,[9] in which the combination of the acid and base is of the type ($acid_4$-$base_2$) through the NH–O and OH–N hydrogen bonds is shown in Fig. 2. It seems that most of the other acid-adenine complex crystals are of a similar type.

It should be noted that many *p*-substituted benzoic acid derivatives do not form the complexes.

Aminoacids. In biological processes some interactions are expected to exist between nucleic acids

TABLE 4. POWDER DATA OF COMPLEXES AND THEIR COMPONENTS

ADENINE-A *

D	INT
3.198	100
6.758	80
5.574	63
3.770	54
2.998	21
3.401	16
3.969	15
5.155	15
2.780	12
3.562	10
2.912	7
4.928	5
2.103	4
2.338	4
1.985	3

ADENINE-B *

D	INT
8.672	100
6.194	73
3.100	62
7.830	50
3.267	48
3.209	34
3.132	32
4.004	32
5.471	25
2.823	20
3.590	18
2.722	16
3.900	11
3.493	10
1.957	9
2.156	9
2.894	9
2.988	9
3.440	9
4.332	9
2.585	7
3.351	7
2.276	6
6.657	6
2.386	5
2.522	5
3.739	5
1.863	4
2.062	4
3.389	4
4.575	4

ADENINE-C *

D	INT
6.657	100
3.198	48
13.392	43
3.278	38
4.439	28
3.619	24
3.028	22
6.109	22
2.921	19
2.959	19
5.906	14
2.212	13
2.501	13
2.867	9
4.647	8
3.363	7
3.770	6
2.023	5
2.442	5
2.730	5
2.321	4
2.607	4

CYTOSINE

D	INT
7.628	100
3.834	68
2.550	41
3.187	26
8.425	9
6.067	7
3.520	5
2.495	4
2.823	3
4.230	3
1.884	2
2.238	1
2.430	1
3.038	1

THYMINE

D	INT
12.450	100
13.810	72
6.237	49
6.970	28
2.321	14
4.152	6
2.998	5
3.480	4
2.644	3
3.121	3
4.745	3
15.237	3
1.989	2
2.780	2
4.647	2
2.045	1
2.080	1
2.858	1
7.695	1

URACIL

D	INT
5.340	100
3.153	68
7.971	55
5.155	41
3.220	30
3.110	20
2.411	15
4.770	13
3.850	12
3.440	9
2.557	8
2.659	8
3.648	8
3.493	7
2.747	5
2.979	5
2.515	4
2.823	4
4.797	4
2.023	2
2.071	2
2.321	2
3.969	2
5.906	2

ALLOXANE

D	INT
7.500	100
6.067	27
3.708	25
4.022	17
2.969	14
2.979	14
3.132	14
2.468	11
2.921	11
2.755	10
2.840	10
3.326	9
3.900	9
2.652	6
5.539	6
1.855	5
2.171	5
4.291	5
5.340	5
5.680	5
2.281	4
4.822	4
8.346	4
2.304	3
2.607	3
2.085	2

O-AMINO-BENZOIC ACID

D	INT
7.971	100
5.829	96
4.004	73
3.351	62
3.786	19
2.840	9
3.453	9
2.912	8
2.607	5
2.498	5
2.196	4
2.675	4
3.048	4
6.417	4
2.002	3
2.141	3
2.238	3
4.720	3
1.929	2
2.045	2
2.315	2
2.449	2
8.845	2
1.969	1
4.439	1

M-AMINO-BENZOIC ACID

D	INT
5.185	100
10.402	37
3.590	26
3.633	20
3.453	16
2.529	14
2.287	13
3.414	13
3.754	13
3.818	13
2.049	12
2.386	12
3.314	9
2.468	8
2.423	7
3.143	7
3.187	7
4.291	6
2.002	5
2.755	4
1.933	3
2.338	2
5.791	2

P-AMINO-BENZOIC ACID

D	INT
5.754	100
6.371	40
4.040	28
5.985	28
9.213	16
2.501	10
2.998	10
2.885	8
2.652	6
4.647	5
3.267	4
2.222	3
2.259	3
2.127	2
2.380	2
3.100	2
3.520	2
1.852	1
1.922	1
3.389	1
3.693	1

2-AMINO-4-METHYL-6-HYDROXY-PYRIMIDINE

D	INT
10.653	100
3.278	40
6.758	22
5.309	10
5.372	9
5.946	5
2.667	2
2.979	2
3.604	2
8.425	2
2.706	1
5.039	1

P-AMINO-SALICYLIC ACUD

D	INT
5.216	100
6.067	93
3.038	71
6.758	68
4.058	50
11.946	48
3.427	35
2.032	18
2.259	16
3.209	13
2.488	10
3.604	9
2.436	8
5.754	8
6.970	8
2.592	7
2.969	7
2.080	6
3.723	6
2.380	4
2.550	4
2.614	4
3.493	4
7.437	4
4.484	1

ANISIC ACID

D	INT
5.505	100
5.246	70
3.534	29
2.468	17
3.934	16
2.501	14
2.481	12
3.079	12
9.309	10
3.351	8
2.755	6
6.707	6
1.945	5
2.040	4
3.723	4
2.304	3
2.350	3
2.522	3
2.714	2
6.109	2
8.425	2
2.797	1

8-AZAADENINE

D	INT
5.405	100
6.607	44
3.153	39
6.970	39
3.619	22
3.453	20
10.782	19
3.110	12
3.297	7
4.152	7
4.506	7
4.874	7
2.969	6
3.048	6
5.754	6
6.194	6
2.867	5
2.659	4
5.985	4
2.344	3
2.706	3
2.171	2
1.922	1
2.080	1
2.222	1

BARBITAL

D	INT
11.051	100
5.539	90
3.693	44
2.763	26
5.340	12
1.845	4
2.212	3
5.011	3
2.536	2
6.067	2

BARUBITJRIC-ACID

D	INT
3.121	100
5.068	68
2.675	17
3.255	5
4.439	5
2.023	4
3.453	4
2.797	3
4.745	3
2.062	2
2.550	2
2.747	2
3.648	2
5.609	2
1.828	1
2.186	1
2.374	1
2.462	1
2.614	1
1.977	0
2.281	0

BENZOIC ACID

D	INT
10.782	100
5.405	65
5.155	30
3.739	23
3.440	13
2.969	11
3.209	10
2.730	9
2.578	8
4.623	8
3.633	7
2.298	4
3.326	3
2.117	2
2.181	2
2.321	2
2.404	2
4.191	2
2.858	1

BENZOLENE-UREA

D	INT
10.526	100
5.340	93
3.562	21
5.829	20
2.894	11
3.351	11
3.480	9
5.039	9
3.633	5
3.058	3
3.754	3
8.425	3
11.787	3
2.667	2
3.132	2
2.222	1
2.321	1

O-BROMO-BENZOIC ACID

D	INT
2.867	100
3.834	90
5.717	65
3.576	29
2.508	24
2.578	14
4.311	13
11.632	12
3.648	10
1.918	8
3.278	8
6.559	8
2.287	7
2.067	5

M-BROMO-BENZOIC ACID

D	INT
12.450	100
6.326	63
4.230	49
3.834	32
3.079	28
2.176	23
4.848	23
5.867	22
1.814	19
3.153	18
3.934	16
1.873	12
2.585	12
2.959	12
2.117	11
2.137	10
3.376	9
3.440	9
2.495	8
2.529	8
3.018	8
2.629	6
2.071	5
2.233	4
2.392	4
2.763	4
2.805	4
2.876	4
3.590	4

5-BROMO-URACIL

D	INT
7.081	100
3.562	58
3.209	57
2.380	28
2.475	21
4.928	18
1.784	16
2.637	10
3.900	10
4.171	9
2.940	8
3.100	8
1.998	7
2.858	7
2.099	4
2.550	4
3.453	4
5.644	4
2.122	3
1.814	2
2.332	2
2.196	2
2.249	2
2.780	2
4.375	2
4.720	2

O-CHLORO-BENZOIC ACID

D	INT
5.829	100
2.940	55
3.917	54
11.632	40
3.243	37
2.430	29
6.758	27
3.770	26
3.604	19
3.678	17
3.187	16
2.557	15
3.453	15
3.143	11
2.265	10
5.068	10
2.380	9
7.138	9
3.018	7
3.089	7
4.171	7
1.965	6
2.222	5
7.762	5
2.094	3
2.788	3
1.981	2
4.695	2

M-CHLORO-BENZOIC ACID

D	INT
6.417	100
3.818	67
3.232	64
4.770	49
2.449	15
4.506	14
2.411	13
2.659	11
3.069	11
3.363	10
3.969	10
3.576	9
2.161	7
1.993	6
2.270	6
9.025	4
2.113	3
2.714	3
2.763	3
5.539	3
2.040	2
2.607	2
1.929	1

P-CYANO-BENZOIC ACID

D	INT
12.810	100
5.754	64
3.187	56
6.371	31
4.332	30
3.576	17
3.648	15
7.138	15
3.255	10
2.254	9
2.309	9
3.058	5
2.675	4
2.714	4
2.867	4
2.912	4
2.217	3
3.363	3
3.427	3
2.161	2

CYANURIC-ACID

D	INT
2.988	100
5.574	44
4.210	18
2.080	4
2.675	4
3.302	4
5.246	4
4.922	3
3.520	3
2.151	1
2.380	1
4.462	1
6.194	1

CYCLOHEXANE-CARBOXYLIC-ACID

D	INT
4.623	100
4.955	50
4.396	40
5.405	37
4.095	35
8.043	32
3.314	16
3.900	12
3.708	8
3.440	6
3.018	5
6.916	5
2.592	3
3.100	3
2.206	2
2.309	2
2.417	2
1.945	1
2.488	1
2.637	1
2.683	1
2.823	1
2.921	1

CYCLOSERINE

D	INT
4.418	100
3.883	81
2.940	30
8.845	30
3.038	16
3.401	15
3.278	14
8.117	14
7.437	11
3.708	9
3.648	8
5.068	8
2.691	7
2.368	4
2.404	4
2.442	4
4.901	4
2.222	3

3,4-DICHLORO-BENZOIC ACID

D	INT
5.405	100
3.883	43
3.153	40
3.232	33
3.100	30
4.901	30
2.212	25
3.028	25
2.780	23
3.708	19
6.194	19
3.278	18
15.504	15
5.185	14
2.386	11
5.829	11
2.578	10
2.698	10
4.004	9
3.507	7

4,6-DIHYDROXY 2-MERCAPTO-PYRIMIDINE

D	INT
9.213	100
3.089	24
2.321	14
3.480	7
3.255	6
3.619	6
4.770	6
3.376	5
1.981	4
2.455	3
3.164	3
3.314	3
2.217	2
2.495	2
2.788	2
2.988	2
7.375	2
10.282	2
2.132	1

O-FLUORO-BENZOIC ACID

D	INT
6.109	100
12.109	50
3.079	39
5.405	39
4.095	35
6.559	14
2.176	12
2.462	12
3.153	12
2.058	11
3.290	11
2.488	8
3.663	8
3.018	8
3.232	8
3.633	6
1.866	5
4.983	3
2.368	2
2.698	2
3.440	1
3.802	1

M-FLUORO-BENZOIC ACID

D	INT
4.077	100
12.109	87
5.405	75
3.834	58
2.036	46
5.039	28
2.462	23
2.156	22
2.522	17
6.109	14
6.417	12
1.845	11
2.212	10
3.232	9
3.633	9
3.314	8
2.368	4
2.578	4
2.698	4
2.315	3
3.028	3
2.797	2

P-FLUORO-BENZOIC ACID

D	INT
5.155	100
12.999	71
3.590	51
3.232	47
3.278	45
4.599	42
6.559	42
5.754	22
2.940	21
2.254	17
2.675	15
2.298	12
2.600	10
3.739	8
2.449	7
2.876	7
2.392	6
3.008	6
1.848	5
2.730	5
4.077	5
6.237	5
1.895	4
2.090	4
2.132	3
3.427	3
2.166	2

FUMARIC ACID

D	INT
3.089	100
3.900	85
3.028	61
2.374	38
2.327	33
3.466	22
3.604	22
3.326	14
3.209	13
2.141	10
3.153	8
4.796	8
2.113	7
2.714	7
2.501	6
2.536	6
2.265	5
2.858	5
1.903	3
1.989	3
2.763	3
2.222	2

HYDANTOIN

D	INT
3.232	100
4.575	50
2.950	17
3.520	12
2.309	8
2.495	5
6.109	5
3.058	4
2.141	2
2.201	2
2.722	2

M-HYDROXY-BENZOIC ACID

D	INT
3.339	100
3.739	98
5.277	89
4.552	64
3.590	58
11.334	57
3.132	50
2.876	38
2.903	26
2.276	24
4.353	22
5.717	20
2.481	19
3.818	18
1.922	16
3.028	14
1.981	13
2.127	13
2.398	9
1.807	7
2.067	7
2.637	7
4.332	7
1.873	6
2.691	6
9.408	6
2.032	5
2.739	5
2.151	4

P-HYDROXY-BENZOIC ACID

D	INT
3.619	100
5.011	71
2.979	54
3.314	54
4.552	27
4.004	16
3.427	14
2.080	13
3.038	12
2.404	10
2.270	9
2.675	9
2.488	7
2.564	7
2.233	6
2.529	5
3.739	5
2.171	4
9.309	4
2.356	3
2.823	3
6.326	3
1.838	2
1.895	2
1.957	2
2.036	2
2.780	1

4-HYDROXY-PTERIDINE

D	INT
6.707	100
6.194	73
6.511	51
5.609	49
3.326	27
3.314	19
3.008	17
5.216	14
12.277	11
3.619	10
3.243	9
3.267	9
4.114	9
2.543	8
2.667	8
3.414	8
4.396	8
2.338	7
4.210	7
5.906	7
11.946	6
2.315	5
3.089	5
2.462	3
3.507	3

ISONICOTINIC-ACID

D	INT
3.401	100
5.340	84
3.187	80
2.233	28
2.392	25
3.619	21
3.100	18
2.254	15
4.484	11
4.095	8
2.659	6
5.717	6
2.094	5
2.931	5
3.723	5
2.876	4
6.151	4
1.884	3
2.468	3
2.449	2
2.529	2
2.714	2

MALEIC ACID

D	INT
3.175	100
3.121	19
3.339	12
3.520	12
3.576	11
3.969	10
2.788	9
5.068	8
2.691	7
5.340	7
2.227	5
2.374	5
2.481	5
2.529	5
2.652	5
2.292	4
2.921	3
4.040	3

NICOTINIC-ACID

D	INT
5.754	100
3.326	74
4.353	74
3.427	60
3.187	52
3.590	49
4.191	38
2.181	28
2.629	23
2.350	19
2.201	12
2.259	11
2.515	9
3.058	9
2.771	7
2.921	7
2.876	6
3.739	6
2.014	5
1.961	3
2.298	3
6.371	3
1.989	2
2.049	2
2.979	2

P-NITRO-BENZOIC ACID

D	INT
5.246	100
3.209	40
3.243	35
10.526	35
2.085	9
1.945	6
2.644	6
2.309	6
2.614	4
2.894	4
2.141	3
2.495	3
3.534	3
4.114	2
5.791	2
6.417	2

5-NITRO-URACIL

D	INT
3.058	100
4.332	29
4.506	29
2.681	25
5.096	25
2.755	24
4.623	23
3.952	22
3.480	21
2.840	20
2.374	19
5.539	16
2.614	15
2.894	13
3.678	13
3.562	10
2.254	9
2.049	8
2.522	8
2.959	8
1.881	7
2.298	6
3.209	5
2.171	4
3.278	4

OROTIC ACID

D	INT
3.110	100
4.529	75
3.018	27
4.928	26
4.022	20
2.270	18
6.371	18
2.023	17
2.315	16
3.209	16
3.917	16
2.885	15
2.411	14
2.417	14
3.401	14
3.427	13
4.848	10
2.564	9
3.576	9
3.818	9
5.680	8
2.108	7
4.114	7
1.841	6
5.155	6
9.118	4

OXALIC ACID

D	INT
3.079	100
5.985	33
5.829	16
4.745	9
3.453	6
2.265	5
2.436	4
1.937	3
1.989	3
2.374	3
2.404	3
2.607	3
2.885	3
2.940	3
2.564	2

PARMITIC ACID

D	INT
11.946	100
7.138	92
18.034	77
5.126	54
1.989	52
2.243	39
9.025	33
28.500	32
3.590	30
2.988	26
4.484	21
2.564	19
3.986	13
13.392	12
2.108	10
9.612	9
1.888	7
3.739	4
5.717	4
7.971	4
2.392	3
4.152	3

1-(2H)-PHTHALAZINONE

D	INT
5.680	100
9.213	75
3.100	36
6.916	31
2.831	20
3.708	16
3.453	14
3.548	14
3.048	13
3.376	13
2.298	8
2.442	7
6.281	7
2.571	5
3.969	5
2.040	4
4.506	4
4.623	4
2.062	3
2.698	3
2.522	1

PICOLINIC-ACID

D	INT
5.039	100
4.822	74
3.363	72
4.332	50
10.048	47
6.511	46
3.187	40
6.607	37
3.678	36
2.217	33
2.276	32
3.562	30
4.928	22
2.683	21
2.652	18
2.885	18
3.290	18
2.090	11
2.171	11
2.814	11
2.191	10
2.430	10
2.488	10
2.771	9
3.079	9
2.309	8
2.959	8
1.941	7
12.628	7
12.999	7
1.998	5
2.103	5
2.127	5
4.114	5
2.374	4
1.910	3
1.961	3
2.027	3
5.574	3

PYRADINIC-ACID

D	INT
6.237	100
3.232	47
4.484	21
3.693	9
2.298	5
3.089	5
2.867	4
2.442	3
3.507	3
2.058	2
2.127	1
2.652	1
2.797	1
2.998	1

PYRADINAMIDE (ALPHA)

D	INT
5.011	100
5.754	54
5.609	47
3.243	37
11.191	29
3.363	22
2.508	21
6.417	15
2.259	12
3.754	10
3.058	9
4.332	7
3.633	6
2.146	4
2.350	4
4.647	4
1.755	3
2.108	3
2.430	3
2.788	3
2.823	3
2.885	3
3.986	3
1.834	1
1.884	1

PYRADINAMIDE (BETA)

D	INT
6.970	100
3.507	70
5.277	60
4.671	50
2.338	44
2.805	22
13.810	14
3.220	9
2.675	8
3.187	8
3.278	7
5.011	7
7.762	7
2.309	6
5.791	6
4.848	5
2.912	4
3.339	4
2.019	3
2.722	3
3.883	3
2.108	1

DL-2-PYRRORIDONE-5-CARBOXYRIC-ACID

D	INT
4.040	100
3.739	59
3.314	53
3.867	49
2.386	33
4.375	33
6.026	32
5.539	30
2.894	29
2.113	23
2.515	19
4.133	16
2.644	14
2.998	14
2.304	13
2.706	12
2.455	10
2.356	9
3.576	9
3.648	8
1.866	7
2.747	7
1.949	6
2.006	6
2.254	6
2.780	6
3.164	6
1.845	5
4.484	5
2.287	4

SALICYLIC-ACID

D	INT
5.155	100
8.043	97
3.520	29
3.175	22
5.754	22
3.100	14
2.912	13
5.609	8
8.845	8
2.259	4
2.368	3
2.529	3
2.659	3
2.797	3
4.506	3
1.926	2
2.571	2
6.371	2
1.941	1
2.053	1
2.730	1

STEARIC ACID

D	INT
13.392	100
8.043	42
20.082	22
5.754	15
2.002	13
2.227	10
4.152	7
10.048	7
3.339	5
3.708	5
4.004	5
4.462	5
2.867	4
2.508	3
5.011	2
2.113	1

SUCCINIC ACID

D	INT
4.439	100
3.414	74
2.849	52
2.222	18
3.351	7
4.928	5
1.907	3
4.058	1

P-TERT-BUTYL-BENZOIC ACID

D	INT
4.770	100
4.462	77
4.447	67
10.402	51
8.425	37
3.969	29
4.375	22
4.230	17
8.758	17
3.770	15
3.507	13
9.100	13

Table 4. continue

3.278	12
5.539	12
3.232	11
5.277	11
6.151	10
3.427	6
2.265	5
2.940	5
3.376	5
5.754	5
2.108	4
2.998	4
7.375	4
2.304	3
2.659	3
6.511	3
2.683	2
2.722	2

THEOPHYLLINE

D	INT
6.067	100
10.048	80
3.302	71
6.657	67
3.326	65
7.695	65
4.796	33
3.373	32
4.983	32
3.834	18
3.708	13
4.210	11
3.018	10
2.571	9
2.763	8
2.592	7
1.926	5
2.171	5
2.675	5
4.418	5
11.051	5
3.520	4
2.338	3
2.392	3
2.495	3
2.522	3
2.867	3
2.894	3
3.576	3
8.506	3
1.817	2
2.222	2
2.249	2
5.309	2
1.841	1
2.281	1

2-THIO URACIL

D	INT
3.187	100
5.791	84
2.894	45
3.376	30
4.506	24
3.453	23
2.600	13
4.077	12
1.804	10
2.543	9
1.941	8
3.018	8
2.380	7
2.780	7
2.979	7
5.068	7
2.755	5
2.254	4
2.449	3
2.481	3
2.002	2
2.287	2
1.973	1
2.132	1

O-TOLUIC ACID

D	INT
11.787	100
3.480	77
5.471	50
3.232	45
3.969	41
3.693	24
6.463	22
3.850	18
2.885	14
5.717	12
3.376	11
3.770	10
5.126	10
4.375	8
7.375	8
3.576	6
2.023	5
2.206	4
2.265	4
2.374	4
2.430	4
2.481	4
2.600	4
4.874	4
1.929	3
2.698	3
4.210	3
1.892	2
2.304	2
1.866	1
4.647	1

M-TOLUIC ACID

D	INT
6.371	100
3.548	18
3.232	12
10.402	12
5.068	8
5.906	8
4.250	7
4.439	6
3.802	5
4.152	4
2.600	3
3.883	3
3.986	3
2.287	2
2.969	2
3.079	2
7.081	2
2.356	1
2.436	1
2.495	1
2.747	1
2.858	1
7.500	1
8.268	1

P-TOLUIC ACID

D	INT
5.126	100
3.339	51
3.562	25
6.026	21
6.371	7
2.564	5
3.018	4
3.934	3
5.680	3
1.831	2
2.462	2
3.069	2
3.198	2

2,4,6-TRIAMINO-1,3,5-TRIAZINE

D	INT
6.707	100
3.363	86
3.466	69
5.011	63
3.100	42
4.095	23
4.040	19
3.302	13
2.455	12
2.998	12
5.906	12
2.683	5
2.940	5
2.243	4
2.344	4

ADENINE + THYMINE

D	INT
11.946	100
5.946	69
3.326	65
6.657	50
8.845	46
3.295	42
5.680	41
4.720	28
11.334	27
4.152	24
2.969	23
3.100	20
5.126	12
3.969	11
2.858	10
3.110	10
2.637	9
2.763	9
4.396	5

CYTOSINE + URACIL

D	INT
5.096	100
7.196	97
4.529	83
3.232	79
4.848	70
2.797	64
6.916	62
2.281	43
9.612	36
13.810	35
2.404	34
3.143	31
2.998	30
3.834	25
4.250	19
2.876	16
3.028	16
2.667	15
8.845	15
3.427	13
2.739	10
2.912	10
6.281	10
1.957	9
7.900	9
3.480	8
7.695	7
2.380	6
2.622	6
2.122	5
2.181	5
2.536	5
3.723	5
2.495	4
1.884	3

ADENINE + ALLOXANE

D	INT
3.351	100
3.187	95
23.251	50
3.548	43
5.680	36
4.623	29
3.723	26
6.810	26
4.439	25
2.921	24
5.906	21
13.598	20
4.822	19
7.628	18
8.588	17
9.408	17
4.928	16
4.291	15
6.194	13

CYTOSINE + ALLOXANE

D	INT
3.255	100
6.511	61
3.986	29
6.970	24
4.396	18
4.647	17
4.552	16
6.707	14
3.153	13
3.440	13
4.270	11
2.392	10
3.376	10
5.438	10
8.117	8
2.350	7
2.014	5
1.870	4
3.079	4
3.604	2

ADENINE + O-AMINO-BENZOIC ACID

D	INT
5.791	100
4.901	81
3.187	77
11.481	52
7.314	50
3.255	45
7.971	45
5.574	40
6.559	38
6.707	37
3.562	33
3.754	32
4.506	30
9.118	25
3.633	22
10.282	21
3.069	20
4.077	17
2.885	16
3.314	16
14.489	16
2.739	15
2.979	15
5.155	15
2.763	14
3.867	11
22.455	9
4.210	8
2.117	6
2.462	6
1.977	4

ADENINE + M-AMINO-BENZOIC ACID

D	INT
3.351	100
3.453	60
5.680	52
5.829	52
3.232	50
3.534	46
11.191	28
6.810	25
6.371	24
3.834	22
3.028	21
3.110	21
6.657	21
2.950	20
3.900	15
4.928	15
2.840	13
4.230	13
4.484	13
8.845	11
12.810	9
5.340	8
9.408	7
2.747	6
8.043	5

ADENINE + P-AMINO-BENZOIC ACID

D	INT
8.268	100
6.194	81
2.771	74
4.152	55
3.302	35
3.466	16
6.916	15
3.220	13
4.983	13
2.969	11
2.233	8
3.934	8
2.080	6
3.069	5
2.176	4
2.698	4
2.831	4
2.921	4
2.058	3
9.118	3
2.495	2
2.543	2

CYTOSINE + 2-AMINO-4-METHYL-6-HYDROXY-PYRIMIDINE

D	INT
6.326	100
6.916	49
3.267	43
8.043	39
4.004	33
4.058	32
12.628	23
3.164	16
3.466	15
2.108	7
3.619	7
2.867	6
2.287	5
2.315	5
3.028	5
4.210	5
4.529	5
5.609	5
1.824	3
2.196	3
2.436	3
2.529	3
2.667	2
5.039	2
2.739	1

ADENINE + P-AMINO-SALICYLIC ACID

D	INT
6.281	100
3.267	91
3.376	46
7.025	23
6.511	15
5.039	14
5.717	14
2.979	12
8.425	9
2.417	8
2.885	8
3.121	8
4.822	8
4.040	7
2.667	6
3.480	6
4.210	6
5.155	6
2.166	4
3.619	4
5.246	4
2.099	3
2.137	3
2.522	3
2.217	2
2.747	2
2.780	2
1.841	1
1.918	1
2.023	1
2.062	1
2.287	1
2.592	1
3.754	1
10.048	1

CYTOSINE + P-AMINO-SALICYLIC ACID -A

D	INT
9.118	100
6.463	96
4.552	48
3.028	39
2.805	20
7.437	17
3.534	8
3.723	8
2.449	7
2.495	7
2.292	6
2.212	5
3.132	5
2.132	4
3.302	4
5.309	4
10.048	4
10.526	4
1.985	3
2.094	3
2.607	3
3.187	3
3.339	3
3.986	3
7.081	3
2.858	2
4.210	2
2.380	1
2.644	1
2.714	1
5.039	1

CYTOSINE + P-AMINO-SALICYLIC ACID -B

D	INT
10.915	100
3.389	94
3.708	93
9.509	75
6.657	71
4.796	64
11.334	64
3.326	46
3.198	42
3.818	32

ADENINE + ANISIC ACID

D	INT
5.471	100
10.915	36
4.210	30
3.663	16
6.371	16
2.747	15
3.255	7
2.592	6
3.100	6
3.562	6
3.363	5
6.067	4
2.321	3
2.931	3

ADENINE + 8-AZAADENINE

D	INT
6.970	100
3.243	78
5.471	46
3.453	37
3.048	25
3.648	20
5.185	16
6.109	15
2.805	14
4.396	11
2.592	9
11.051	7
2.027	6
2.315	6
3.867	4
2.141	3
4.133	3
7.900	3
9.309	3

THYMINE + 8-AZAADENINE

D	INT
6.862	100
5.471	85
3.232	29
12.450	25
3.648	20
3.427	18
13.810	17
5.155	16
6.026	16
3.018	15
11.051	12
4.375	11
2.788	8

ADENINE + BARBITAL

D	INT
5.906	100
11.787	58
3.401	49
3.232	17
2.950	16
3.562	15
5.539	15
2.979	14
3.110	14
4.439	12
4.671	9
5.185	9
3.900	8
2.196	5
2.622	5
2.698	5
3.754	5
7.762	5
2.309	4
2.788	4

ADENINE + BARBITURIC-ACID

D	INT
6.281	100
3.232	98
5.155	73
3.058	70
3.604	65
3.562	61
3.633	59
3.143	57
7.196	55
2.814	42
4.955	33
2.730	26
2.564	23
2.637	18
5.946	18
3.834	15
4.004	15
2.449	14
4.575	14
2.146	12
2.270	12
2.227	6
4.396	5

CYTOCINE + BARBITURIC-ACID

D	INT
3.267	100
14.255	58
5.216	38
4.004	22
4.040	22
3.453	20
4.506	20
3.389	17
7.081	17
2.921	15
3.678	13
2.698	12
8.425	12
4.230	11
2.404	9

ADENINE + BENZOIC ACID

D	INT
13.810	100
3.363	59
3.121	32
3.453	29
6.916	25
5.405	18
4.745	17
3.243	14
3.818	14
5.906	14
4.133	11
4.671	11
5.277	11
3.058	10
3.187	9
4.171	9
4.332	9
2.771	7
7.695	7
9.718	6
2.298	5
11.051	5
2.840	4
2.998	4
4.040	4
6.371	4
1.977	3
2.714	3
3.723	3
1.884	2
2.049	2
2.374	2
2.436	2
2.501	2

CYTOSINE + BENZOIC ACID

D	INT
21.551	100
5.574	93
3.198	61
10.782	56
3.255	36
4.462	35
5.405	32
7.628	31
4.191	28
2.797	21
3.739	19
4.040	18
7.375	18
3.326	14
6.109	14
2.350	12
2.607	12
2.488	11
3.100	11
3.834	11
2.543	10
2.714	10
2.831	10
2.998	9
3.520	8
3.648	8
2.298	7
2.950	6
3.401	6
4.848	6
4.955	5
1.937	4
2.238	4
1.961	2
2.161	2

ADENINE + BENZOLENEURFA

D	INT
5.372	100
10.782	95
7.437	90
12.999	74
6.463	73
7.138	48
3.326	35
3.576	30
3.100	29
6.109	28
3.466	26
3.708	26
14.979	19
3.663	18
4.311	15
3.232	14
3.018	11
5.867	11
2.903	9
2.156	8
2.468	8
4.671	7
5.068	6
2.108	5
2.667	5
4.770	5
8.672	5
2.515	4
8.192	4
4.114	3

ADENINE + O-BROMO-BENZOIC ACID

D	INT
3.326	100
5.068	20
5.754	18

CYTOSINE + O-BROMO-BENZOIC ACID

D	INT
5.791	100
3.867	94
3.401	82
2.903	73
3.678	71
5.471	69
3.018	38
3.220	38
4.058	35
3.339	32
3.562	28
2.780	23
5.277	22
3.058	21
2.667	20
2.805	19
10.915	17
4.874	16
9.509	15
6.151	14
11.481	12
2.515	11
2.404	10
5.126	10
2.585	8
1.941	7
2.040	7
2.156	7
4.484	7
2.327	6
1.866	5
2.249	5
1.903	4

ADENINE + M-BROMO-BENZOIC ACID

D	INT
3.302	100
3.663	41
4.133	34
4.745	30
3.507	28
4.623	24
3.175	23
3.363	22
4.484	19
2.998	16
2.564	15
5.574	15
5.155	14
5.471	14
2.196	13
3.739	13
6.810	13
2.171	11
2.921	11
3.867	11
4.270	10
2.814	8
1.929	7
6.326	7
2.127	6
2.380	6
2.404	6
3.969	6
1.981	5
2.067	5
2.730	5
8.845	5
2.032	4
7.314	3

CYTOSINE + M-BROMO-BENZOIC ACID

D	INT
4.396	100
4.745	88
2.714	62
4.058	62
4.171	43
3.562	31
3.678	31
2.040	24
2.442	23
5.906	22
2.929	19
5.277	19
2.222	17
2.380	17
3.100	16
2.151	15
3.818	14
12.277	13
23.879	13
2.356	12
3.493	12
6.237	12
2.592	11
2.931	10
1.881	8
2.780	8
8.346	8
4.848	8
3.278	7
3.326	7
4.874	6
7.138	6
9.213	6
3.187	5
1.941	4
2.814	4

ADENINE + 5-BROMO URACIL

D	INT
3.255	100
2.979	54
3.187	43
3.058	38
5.829	35
3.770	33
5.539	32
6.607	32
2.564	28
2.600	28
2.805	26
3.143	26
3.590	26
9.025	26
2.622	23
3.867	23
3.401	21
12.628	21
18.409	21
10.782	19
4.171	18
4.848	18
7.437	18

CYTOSINE + 5-BROMO URACIL

D	INT
3.232	100
3.427	83
6.810	73
4.874	65
2.950	59
3.590	52
3.917	52
2.867	51
2.637	43
2.481	37
2.356	34
3.110	33
2.417	32
3.290	32
11.632	32
7.138	28
9.826	25
4.623	24
3.770	22
2.797	20
4.077	18
8.117	18
2.006	17
2.564	16
7.695	13
2.171	12
4.375	12
5.906	12
2.201	10
2.132	9
2.254	9

THYMINE + 5-BROMO URACIL

D	INT
3.278	100
11.946	77
3.243	61
4.077	35
2.876	33
2.629	28
2.931	24
3.507	24
6.067	24
1.989	18
2.032	18
2.045	18
2.722	18
3.934	17
4.745	16
2.578	15
3.562	15
2.243	14
2.398	14
5.680	11

ADENINE + O-CHLORO-BENZOIC ACID

D	INT
6.371	100
18.801	33
3.187	18
9.309	16
3.401	5
2.132	4
2.755	4
2.931	4
3.754	4
3.834	4
5.096	3
5.539	2
7.081	2
2.259	1

CYTOSINE + O-CHLORO-BENZOIC ACID

D	INT
3.376	100
5.471	70
3.198	52
3.648	46
2.979	27
2.747	26
2.652	21
5.906	18
4.022	13
3.934	10
3.818	8
4.848	8
10.782	8
2.141	7
5.155	7
2.564	6
2.032	5
2.508	5
11.946	4
1.957	3
1.863	2

ADENINE + M-CHLORO-BENZOIC ACID

D	INT
6.151	100
4.418	82
3.604	49
5.829	34
3.739	21
2.508	20
3.100	19
4.770	19
3.326	16
6.916	15
9.213	15
3.038	14
4.623	14
7.830	14
3.198	13
3.883	13
2.979	9
3.466	9
7.437	9
11.632	9
2.858	8
2.912	8
2.404	6
2.356	5
2.629	5
2.227	4
17.673	4
2.067	3
2.156	3
2.201	3
2.691	3

CYTOSINE + M-CHLORO-BENZOIC ACID

D	INT
4.353	100
4.720	80
3.986	63
5.867	54
2.667	52
5.309	33
3.648	31
2.515	28
3.018	28
7.025	27
3.520	23
4.152	21
6.151	20
2.010	19
2.350	19
3.058	19
2.117	15
22.655	15
2.249	13
2.321	12
2.380	12
2.564	12
2.404	10
2.156	9
2.903	9
3.243	9
3.802	8
6.463	7
2.455	6
1.910	3
1.929	3
1.949	3

ADENINE + CYANURIC ACID

D	INT
3.243	100
8.425	39
9.025	20
4.983	14
3.028	10
4.230	4
5.405	4

ADENINE + CYCLOHEXANE-CARBOXYLIC-ACID

D	INT
18.409	100
4.291	35
4.671	34
3.969	30
3.290	29
6.194	28
3.648	15
5.867	15
3.187	14
3.708	12
11.632	12
2.667	10
5.216	8
2.912	7
2.959	7
3.401	7
4.955	7
3.534	6
4.484	6
5.574	4
6.758	4
8.845	4
9.309	4
2.831	2

CYTOSINE + CYCLOHEXANE-CARBOXYLIC-ACID

D	INT
12.999	100
4.439	91
7.563	33
3.834	31
3.648	20
4.152	17
3.187	15
4.004	12
4.770	11
5.867	10
3.326	9
2.607	8
4.623	8
2.557	7
3.520	7
3.278	6
4.901	5
5.068	5
2.227	4
2.344	4
6.151	4
2.488	3
2.921	3
3.028	3
8.346	3
2.675	2
5.372	2

ADENINE + CYCLOSERINE

D	INT
3.220	100
3.187	83
6.707	51
7.081	51
5.126	36
5.574	34
3.739	31
3.493	29
3.867	17
3.376	16
3.314	15
2.979	14
7.762	13
3.058	11
2.417	7
4.396	7
2.797	6
4.291	6
4.575	4
6.151	2

ADENINE + 3,4-DICHLORO-BENZOIC ACID

D	INT
3.278	100
6.326	37
7.138	25
6.237	23
7.255	23
5.505	20
3.633	17
3.754	14
2.780	12
4.720	12
4.848	12
2.867	9
4.114	4

CYTOSINE + 3,4-DICHLORO-BENZOIC ACID

D	INT
5.096	100
2.814	36
3.326	31
4.040	29
8.506	26
12.628	19
4.955	18
3.164	16
2.488	15
2.298	13
3.058	13
3.255	13
3.619	13
4.484	13
6.194	12
2.344	10
3.427	10
2.156	8

ADENINE + 4,6-DIHYDROXY-2-MERCAPTO-PYRIMIDINE

D	INT
10.526	100
9.408	64
3.480	50
2.607	47
3.302	28
3.110	23
5.216	21
2.442	15
3.220	15
2.071	14
2.332	12
2.557	12
3.187	12
4.077	10
5.068	10
3.351	8
2.233	6
2.998	6
7.437	6
1.973	5
2.675	5
2.771	4
3.619	4
1.998	3
2.040	3
2.108	3
2.191	3
2.858	3

CYTOSINE + 4,6-DIHYDROXY-2-MERCAPTO-PYRIMIDINE

D	INT
3.302	100
4.901	87
3.278	72
6.067	65
9.309	65
4.040	63
3.917	44
9.826	40
4.647	37
5.680	34
2.885	26
2.557	24
2.356	22
3.453	22
4.695	21
5.126	21
2.840	20
2.979	19
6.862	18
2.622	16
3.089	15
5.011	14
2.315	13
3.209	13
3.414	13
3.633	13
1.693	12
2.442	12
3.143	11
1.957	9
2.076	8
2.501	8
2.238	8
3.008	8
1.937	7
2.730	7
12.109	7
2.201	6
2.763	6
2.411	5
7.695	5
2.040	4
4.353	4

ADENINE + O-FLUORO-BENZOIC ACID

D	INT
4.529	100
7.255	81
3.187	49
4.095	49
6.194	43
9.718	39
6.326	36
12.810	36
3.619	32
5.309	31
5.216	30
2.423	29
3.466	26
2.233	21
3.466	15
2.276	14
2.831	14
2.309	13
3.562	13
2.771	11
1.817	10
2.108	10
1.870	9
2.578	9
2.667	9
2.885	9
2.931	9
2.969	9
2.969	7
2.600	6
3.038	6
3.754	6
2.181	5
2.515	5
4.291	5
3.900	4
17.673	4

CYTOSINE + O-FLUORO-BENZOIC ACID

D	INT
7.081	100
3.132	86
3.232	86
4.671	53
4.250	49
3.562	48
5.185	33
4.040	32
2.309	21
6.511	17
6.281	16
3.058	13
2.350	9
9.309	9
2.592	8
3.867	6
1.918	4
2.099	4
2.243	4
2.462	4
1.941	3
2.156	3
2.501	3

ADENINE + M-FLUORO-BENZOIC ACID

D	INT
3.243	100
13.392	40
6.237	35
3.187	34
3.351	27
3.548	25
20.020	25
5.754	24
3.507	22
6.463	19
6.758	19
3.723	18
6.657	17
4.552	14
5.216	13
10.048	12
8.043	11
4.671	9
5.539	9
4.928	8
2.706	6
4.462	6
2.858	5
4.396	5
4.171	4
2.233	3
2.780	3

CYTOSINE + M-FLUORO-BENZOIC ACID

D	INT
3.285	100

Table 4. continue

3.164	42
4.311	53
5.185	53
6.511	52
4.114	48
4.647	36
3.590	29
6.237	25
7.138	21
9.408	18
2.321	17
3.493	17
5.505	14
5.906	14
2.374	13
2.629	13
3.648	13
3.900	13
7.375	8
2.141	7
2.481	7
2.739	7
2.797	7
3.786	7
2.265	6
2.592	6
18.409	6

ADENINE + P-FLUORO-BENZOIC ACID

D	INT
3.314	100
5.405	71
7.375	69
3.453	34
2.840	30
6.109	27
8.758	19
3.678	18
2.912	14
3.100	13
2.755	12
10.402	10
14.730	9

CYTOSINE + P-FLUORO-BENZOIC ACID

D	INT
5.906	100
6.916	45
3.187	41
17.327	35
3.255	33
4.874	29
3.389	27
4.439	27
3.507	26
5.505	18
13.810	13
3.850	10
2.780	8
3.028	8
2.730	6
2.578	5
9.826	5
2.959	1

ADENINE + FUMALIC ACID

D	INT
6.463	100
3.376	41
4.874	30
4.462	25
11.051	21
5.340	19
6.916	18
3.708	17
4.077	17
13.392	17
2.578	15
3.648	14
4.210	13
4.270	13
2.227	12
2.592	12
2.442	11
5.867	10
2.714	9
5.609	9
2.550	8
2.969	8
3.069	8
3.209	8
3.453	8
5.539	8
2.287	6
3.100	6
3.562	6
8.425	6
9.408	6
2.386	4
7.830	3

CYTOSINE + FUMALIC ACID

D	INT
4.770	100
3.267	56
3.376	43
3.850	41
3.048	35
7.695	22
6.511	19
2.998	17
2.404	12
3.562	11
14.255	9
2.849	8
2.380	7
2.233	5
5.906	4
2.141	3
2.270	3

ADENINE + HYDANTOIN

D	INT
3.278	100
4.332	16
7.900	16
4.848	13
6.237	12
6.511	9
4.623	7
3.028	6
2.270	5
3.883	4

ADENINE + M-HYDROXY-BENZOIC ACID

D	INT
3.363	100
3.220	85
5.096	74
3.414	62
3.534	56
7.255	55
3.604	54
6.026	46
5.372	44
3.069	40
4.822	30
3.708	26
2.912	21
2.550	17
8.672	16
2.730	14
2.780	14
2.344	11
2.404	10
2.058	8
2.191	8
2.006	7

CYTOSINE + M-HYDROXY-BENZOIC ACID

D	INT
4.353	100
4.484	72
5.068	66
3.883	60
5.309	50
3.648	44
3.576	43
18.034	41
5.906	40
6.026	40
8.672	38
3.548	36
3.339	32
2.940	28
2.600	25
6.237	24
3.038	22
2.529	21
2.894	21
13.598	20
3.079	19
4.191	19
3.232	15
2.398	12
2.417	11
2.243	10
6.511	10
2.006	9
2.667	7
2.755	7

ADENINE + P-HYDROXY-BENZOIC ACID

D	INT
3.326	100
5.609	93
3.198	87
3.480	58
2.969	51
5.372	51
2.805	42
7.255	33
3.110	27
4.901	25
3.850	23
4.191	19
5.096	17
8.506	15
11.632	15
6.326	12
2.151	11
10.782	11

CYTOSINE + P-HYDROXY-BENZOIC ACID

D	INT
4.770	100
7.196	18
14.029	14
2.398	10
3.590	10
2.867	9
3.363	8
3.048	7
3.534	6
3.198	5
3.802	3
4.133	3
2.667	2
5.277	2
6.109	2
6.417	2
7.695	2

CYTOSINE + 4-HYDROXY-PTERIDINE

D	INT
5.906	100
3.427	85
5.754	77
3.132	66
6.707	40
4.822	31
9.826	30
4.623	22
7.138	22
3.850	20
2.840	16
3.232	13
3.986	13
11.632	11
7.762	10
2.637	8
2.287	6
2.392	6
2.706	6
2.156	5
2.755	5

CYTOSINE + ISONICOTINIC-ACID

D	INT
17.327	100
3.290	63
5.791	59
3.401	57
3.986	53
5.309	48
3.175	44
4.353	37
2.495	30
6.916	29
3.480	28
2.903	27
4.720	25
8.672	18
3.089	17
2.238	13
2.386	11
2.979	11

ADENINE + MALEIC ACID

D	INT
3.209	100
6.326	44
3.069	37
9.408	37
2.931	33
4.506	31
3.351	28
8.268	28
3.576	26
3.883	25
3.440	24
5.539	18
2.508	13
4.874	13
2.132	12
2.259	11
2.332	10
2.171	8
2.430	8
2.014	5
2.053	5
5.906	5

CYTOSINE + MALEIC ACID

D	INT
3.164	100
4.874	61
7.971	23
3.678	19
5.216	19
3.786	18
2.959	16
3.917	16
3.326	15
2.667	13
3.187	11
2.849	11
2.515	10
2.430	9
2.488	9
3.058	8
2.455	7
2.755	7
3.507	6
1.953	5
2.049	5
2.108	5
2.176	5
2.062	4
6.511	3
2.243	2

ADENINE + NICOTINIC ACID

D	INT
7.138	100
5.277	45
4.745	17
3.934	13
3.110	12
3.018	11
3.220	11
3.619	11
7.695	11
2.380	8
2.571	8
11.632	7
2.849	6
2.249	5
6.067	5

CYTOSINE + NICOTINIC ACID

D	INT
5.405	100
4.575	91
14.255	83
2.867	81
2.362	72
4.152	68
7.138	64
2.571	42
8.346	34
11.051	31
4.770	26
2.979	25
2.032	23
2.181	23
3.290	18
2.488	14
3.633	14
2.771	13
3.164	12
6.607	11
3.389	9
2.132	8
2.298	7
2.430	5
2.076	4
2.103	4
1.953	3
2.249	3

ADENINE + P-NITRO-BENZOIC ACID

D	INT
5.438	100
3.209	40
6.417	28
2.722	8
3.267	7
3.389	7
4.311	7
6.026	6
3.548	5
4.575	5
6.862	5
3.008	4
2.156	3
2.117	2
2.356	2

CYTOSINE + P-NITRO-BENZOIC ACID

D	INT
5.438	100
6.326	44
3.267	36
4.250	31
6.237	25
3.507	17
4.171	14
2.921	10
3.339	9
4.695	9
3.143	7
4.955	7
2.411	6
3.008	6
2.254	5
2.122	4
2.722	4
2.062	3
2.652	3
3.648	3
4.484	3
5.126	3
12.450	3
1.922	2

ADENINE + 5-NITRO URACIL

D	INT
3.363	100
3.132	87
5.754	61
5.471	59
3.314	57
3.069	53
3.018	45
3.548	38
2.831	24
2.747	20
4.077	20
4.114	19
2.304	18
6.067	17
2.176	13
4.291	13
6.607	12
4.623	9
3.818	8

CYTOSINE + 5-NITRO URACIL

D	INT
3.121	100
6.194	97
4.874	57
3.520	40
5.505	35
3.187	32
3.389	30
5.277	29
3.018	24
3.339	24
2.571	20
2.722	18
10.526	18
2.921	17
2.270	13
8.192	11
3.802	8
2.249	6
2.831	6
3.986	6
2.201	5
2.368	5

ADENINE + OROTIC ACID

D	INT
3.164	100
3.493	61
4.623	61
5.340	31
3.648	29
8.043	27
6.067	21
2.858	20
2.959	20
2.332	18
2.831	18
3.351	18
4.004	18
3.038	12
4.529	10
2.495	9
2.206	8
2.067	7
2.683	7
3.818	6
4.291	5
2.423	4
6.810	4

CYTOSINE + OROTIC ACID

D	INT
13.598	100
3.164	72
6.810	47
5.680	34
3.314	32
4.506	25
4.040	21
2.508	20
2.298	19
2.356	17
2.462	17
3.770	16
6.511	16
3.850	15
2.959	13
4.671	13
2.876	12
5.216	12
9.213	11
11.191	11
2.233	10
3.534	10
10.526	9
5.126	8
6.026	8
16.994	8
2.667	7
2.714	6
4.270	6
5.438	6
2.430	5
2.191	4
7.563	4
1.910	2
2.132	2

ADENINE + OXALIC ACID

D	INT
3.220	100
4.955	71
3.802	30
5.717	27
7.375	26
3.153	23
3.326	22
2.600	15
3.401	12
2.894	10
3.534	9
2.201	8
2.722	8
2.522	7
4.191	6
5.405	6
5.946	6
7.830	6
8.346	6
3.883	5
2.374	4
4.040	4
2.151	3
1.888	2
2.019	2
2.067	2

CYTOSINE + OXALIC ACID

D	INT
5.754	100
5.155	92
4.671	84
4.484	61
7.762	54
2.332	49
3.440	39
3.723	38
10.402	36
5.906	34
2.998	31
3.089	30
2.814	29
3.376	29
2.876	25
2.578	23
2.515	19
2.259	18
2.950	18
5.068	17
2.849	16
2.386	15
3.326	14
3.867	13
2.212	12
2.675	11
2.141	10
2.607	9
1.918	8
3.255	7
3.934	7
2.103	6
3.132	6
2.085	5
1.957	4
2.747	4
4.114	3

ADENINE + PARMITIC ACID

D	INT
14.029	100
21.038	71
3.648	55
4.720	32
4.529	30
3.278	27
3.302	24
4.439	19
8.425	19
10.526	17
3.187	16
3.969	16
7.025	15
4.191	13
6.026	12
6.707	8
4.983	7
5.246	7
2.103	6
2.309	6
9.509	6
2.592	4

ADENINE + 1-(2H)-PHTHALAZINONE

D	INT
17.327	100
5.155	83
3.302	75
8.672	52
3.079	46
4.332	37
3.562	36
3.453	31
7.563	28
2.876	20
2.683	13
5.754	12
3.209	10
2.508	9
3.648	9
3.834	5
2.212	4
6.417	4
2.137	3

CYTOSINE + 1-(2H)-PHTHALAZINONE

D	INT
8.425	100
8.506	98
4.022	86
2.637	48
3.326	14
6.067	9
9.509	9
6.607	8
2.304	7
3.693	7
1.945	4
2.931	4
1.929	3
4.484	3
10.402	2

ADENINE + PICOLINIC ACID

D	INT
6.810	100
5.717	85
4.529	50
7.437	45
8.845	37
10.782	27

CYTOSINE + PICOLINEC ACID

D	INT
18.801	100
3.209	89
4.599	86
6.607	86
5.216	83
7.900	77
3.314	67
5.039	67
4.796	64
3.786	61
3.952	61
4.210	61
4.695	61
4.928	61
2.797	56
2.885	52
3.440	52
10.048	52
12.109	49
8.672	44
9.509	43
2.362	37
2.730	35
2.449	34
2.622	32
3.633	32
6.067	29
2.386	28

CYTOSINE + PYRADINIC ACID

D	INT
13.810	100
4.671	99
5.216	40
3.175	33
2.423	23
6.970	23
2.644	22
5.985	17
3.739	15
3.562	14
2.137	13
2.368	12
2.912	12
2.805	10
4.004	10
2.276	7
2.698	7
3.480	7
2.006	6
2.067	6
2.522	6
2.969	6
2.191	5
3.900	5
1.926	4

ADENINE + PYRADINAMIDE (BETA)

D	INT
7.830	100
8.672	67
6.194	57
3.883	39
3.089	36
5.277	34
4.004	24
7.025	20
5.438	17
2.814	13
1.945	12
2.585	9
3.590	8
2.722	7
3.507	7
4.695	7
2.151	6
2.683	6
3.739	6
2.876	4
4.311	4
2.344	3
3.243	3
3.389	3
2.002	2
2.062	2
2.309	2
9.509	2
2.113	1
2.281	1
2.398	1

ADENINE + DL-2-PYRRORID-ONE-5-CARBOXY-LIC ACID

D	INT
12.810	100
22.655	53
15.781	50
3.290	25
7.628	22
5.155	21
13.598	18
3.187	17
14.730	15
5.644	14
3.754	12
4.040	12
2.959	11
3.153	11
4.396	11
4.901	11
3.818	10
2.622	9
3.089	9
3.548	9
3.648	8
2.747	7
4.599	7
6.758	7
7.138	7
2.903	6
4.270	6
5.340	6
10.164	6
2.823	5
6.026	4
2.315	3
2.362	3

CYTOSINE + DL-2-PYRRORID-ONE-5-CARBOXY-LIC ACID

D	INT
3.480	100
4.439	55
3.100	41
3.633	16
4.077	15
5.791	14
8.192	10
11.632	9
2.622	5
4.575	5
7.138	5
3.867	4
2.885	3
5.438	3
6.326	3
2.321	2
2.557	2

ADENINE + SALICYLIC ACID-A

D	INT
7.500	100
5.039	41
5.246	27
5.609	27
3.187	26
14.979	26
3.480	24
8.043	23
4.462	22
3.220	21
6.417	20
3.153	18
10.526	15
20.549	11
3.986	9
3.278	7
3.008	6
3.708	6
2.797	5
1.933	3
2.233	3
2.321	2
2.191	1
2.014	1

ADENINE + SALICYLIC ACID-B

D	INT
3.278	100
17.673	83
3.934	58
6.237	58
5.644	52
3.187	42
5.867	41
6.067	40
3.739	35
2.771	22
5.039	21
3.389	20
8.588	20
4.418	16
4.796	16
5.126	15
2.921	13
3.132	13
2.988	11
3.520	11
5.216	11
2.585	9
2.823	8
4.114	8
6.916	8
2.321	6
3.633	6
7.025	6
8.934	6
2.019	5
2.094	5
2.392	5
2.206	4
2.265	4
2.691	4
10.282	3

CYTOSINE + SALICYLIC ACID

D	INT
3.209	100
3.121	90
4.311	69
5.216	65
7.196	52
4.004	29
3.900	25
4.191	19
2.309	17
3.069	15
4.506	13
3.534	12
3.590	12
6.237	11
2.747	9
2.287	8
6.511	8
2.637	7
4.575	7
1.973	5
2.475	5
2.607	5
2.814	5
2.564	4
2.053	3
2.156	3
2.430	3
3.453	3
5.754	3
8.934	3
2.495	2
28.500	2
4.770	2

ADENINE + STEARIC ACID

D	INT
16.365	100
15.237	27
24.543	24
23.251	10

ADENINE + SUCCINIC ACID

D	INT
3.290	100
4.623	18
3.376	17
3.507	13
4.770	11
5.829	11
5.405	10
3.453	8
3.619	7
3.969	7
5.505	7
8.845	6
2.730	5
2.629	4
2.292	3
2.840	3
4.353	3
2.550	2

CYTOSINE + SUCCINIC ACID

D	INT
3.267	100
5.717	75
4.770	32
4.848	21
4.955	16
3.079	15
2.141	14
3.414	14
5.277	14
3.834	13
5.985	13
2.386	12
3.153	12
3.576	12
2.206	11
2.858	10
3.351	10
3.028	9
14.255	9
4.210	7
4.599	7
6.559	7
2.430	6
2.675	5
3.678	5
2.321	4
2.959	4
1.989	3
2.607	3
2.730	3
3.952	3
7.138	2

ADENINE + P-TERT-BUTYL-BENZOIC ACID

D	INT
13.810	100
4.270	39
3.562	38
5.277	34
4.647	30
4.133	28
3.038	25
3.453	25
12.109	25
4.004	23
4.077	21
6.511	16
6.970	15
6.067	13
4.418	11
2.849	6
5.754	6
3.100	5
11.051	5
2.931	4

CYTOSINE + P-TERT-BUTYL-BENZOIC ACID

D	INT
22.089	100
7.695	64
4.529	57
5.505	33
3.850	20
3.376	16
4.983	13
2.840	12
2.495	10
3.663	10
3.143	9
4.095	8
4.822	8
2.259	6
2.780	6
3.562	6
4.210	6
2.270	5
2.543	5
3.209	5
4.270	5
4.396	5
5.309	5
6.109	5
6.970	4
2.298	3
5.754	3

ADENINE + THEOBROMINE

D	INT
11.481	100
8.672	35
6.194	28
5.609	21
3.723	18
5.340	18
3.290	17
8.192	17
3.187	14
6.559	14
2.979	11
3.351	11
6.758	11
3.453	9
3.590	9
4.133	8
5.096	8
3.058	7
2.831	6
2.903	5
2.805	4
4.353	4
2.755	3
4.529	3

ADENINE + THEOPHYLLINE

D	INT
7.314	100
3.326	76
5.791	42
7.563	33
3.739	18
5.277	17
6.707	17
3.220	12
6.607	11
4.848	10
3.693	9
2.894	7
2.430	6
2.988	5
3.048	5
3.850	5
8.043	4

CYTOSINE + THEOPHYLLINE

D	INT
2.988	100
7.138	36
5.574	32
6.326	17
2.374	16
12.628	16
3.520	12
2.259	6
3.678	6
1.945	5
2.090	3
2.287	3
2.468	3
4.928	3
2.006	2
2.763	2

ADENINE + 2-THIO URACIL

D	INT
5.039	100
3.314	83
6.559	81
5.539	66
3.132	63
3.198	50
3.633	32
3.723	32
3.770	27
8.192	27
4.484	26
2.691	23
5.829	22
3.507	19
11.191	17
5.309	16
8.588	16
2.763	12
2.921	12
3.834	12
4.230	11
6.026	11
11.632	10
9.936	8

ADENINE + O-TOLUIC ACID

D	INT
4.647	100
6.194	94
3.867	70
3.278	60
4.332	57
3.220	43
13.598	41
2.867	33
5.791	23
3.493	20
3.952	20
6.916	17
3.678	15
3.110	11
3.038	10
2.797	9
2.592	8
5.216	7
1.752	6
2.085	4
2.176	4
2.010	3
2.270	3

CYTOSINE + O-TOLUIC ACID

D	INT
3.314	100
5.644	32
3.786	22
3.739	18
2.814	16
6.511	10
5.791	7
7.563	6
4.191	5
6.607	3

ADENINE + M-TOLUIC ACID

D	INT
13.598	100
6.916	26
5.011	25
3.243	20
5.609	20
3.619	19
3.187	18
3.507	16
4.599	16
3.754	11
3.038	10
10.402	8
4.462	6
2.780	5
3.917	4
2.659	2
2.449	1

CYTOSINE + M-TOLUIC ACID

D	INT
13.192	100
6.281	99
3.534	64
3.187	48
4.822	42
3.132	40
4.311	36
7.628	35
3.089	34
2.495	25
10.402	25
3.290	23
6.026	23
4.133	22
3.786	19
2.998	16
3.440	16
3.850	15
3.969	15
2.739	13
2.698	11
4.484	11
2.823	10
3.648	10
2.238	8
2.386	8
2.940	8
6.758	8
2.430	7
5.039	7
2.292	6
2.644	6
2.006	2

ADENINE + P-TOLUIC ACID

D	INT
3.267	100
15.237	56
6.417	30
3.175	22
3.562	18
6.916	17
7.900	17
3.693	16
3.401	15
3.969	14
5.096	11
4.928	10
5.340	10
5.680	10
3.069	9
4.418	9
5.906	9
2.940	8
4.270	7
4.623	6
2.176	5
2.840	5
10.282	4
2.468	3
2.659	3

THYMINE + 2,4,6-TRIAMINO 1,3,5-TRIAZINE

D	INT
8.192	100
3.326	82
5.039	31
2.536	24
4.745	23
3.401	21
3.100	20
3.232	15
4.114	15
5.185	13
5.985	11
6.758	11
2.156	10
2.747	9
2.814	9
2.998	9
3.507	9
5.405	9
4.040	8
11.632	8
2.362	7
3.648	7
9.118	5

URACIL + 2,4,6-TRIAMINO 1,3,5-TRIAZINE

D	INT
7.375	100
3.164	72
8.672	50
3.708	22
2.338	21
5.039	20
2.771	19
2.921	18
3.326	18
4.270	18
4.623	18
2.468	15
3.220	15
2.629	12
3.255	12
3.493	12
4.375	12
2.137	11
2.309	9
1.852	8
1.895	8
2.032	8
2.113	8
3.058	8
6.970	8
7.971	8
2.522	7
2.840	7
3.619	7
6.109	6
1.873	5
2.222	5
2.585	5
2.722	5

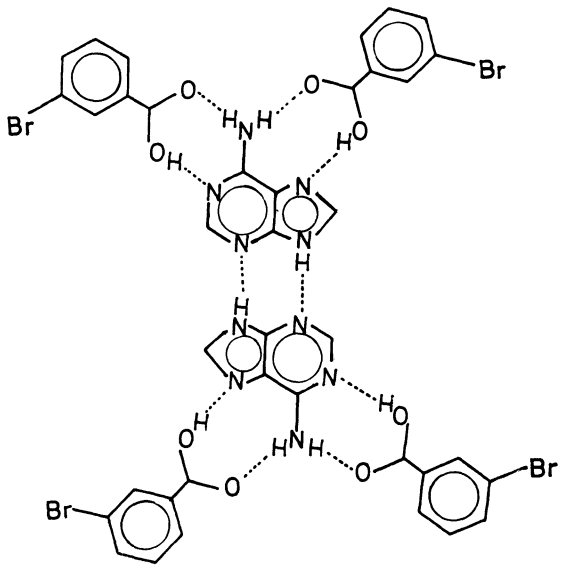
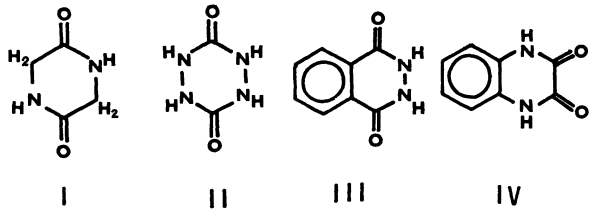


Fig. 2. The hydrogen bonding system of the complex crystal between *m*-bromobenzoic acid and adenine.

and amino acids. However, no amino acids were found to interact with these bases under the present conditions. The zwitter-ion form of amino acid might be related to this inertness. The substances tested in the present study were glycine, α-alanine, β-alanine, L-serine, L-threonine, L-valine, L-leucine, L-isoleucine, L-asparatic acid, L-histidine, L-proline, arginine, tryptophan, phenylalanine, methionine, cystein, creatine, and aminocapronic acid.

Acid Amides and Lactams. In view of complex-forming ability, acid amides and lactams could be classified into four categories (3 to 6) as shown in Table 3. Acid amides are inert; compounds tested are benzamide, *o*-, *m*-, and *p*-toluamide, *o*-, *m*-, and *p*-hydroxy benzamide, *o*-, *m*-, and *p*-chlorobenzamide, picolinamide, nicotinamide, and isonicotinamide. The only exception in amide group is pyrazinamide which can bind with adenine. Lactam group are inactive; the compounds tested are butyrolactam, valerolactam, ε-caprolactam, 2-azacyclononanone, tetrahydro-2-pyrimidone, succinamide, maleimide, phthalimide, glycinanhydride, 1,3-dimethylurea, acetylurea, 1-acetyl-3-methylurea, 1-phenyl-3-acetylurea. 1,3-diphenylurea, phenylurea, benzylurea, benzoylurea, and acetanilide.

Although the linear molecules containing CO and NH groups (category 4) do not interact with the bases, the corresponding atomic arrangement in cyclic molecules bind with adenine and/or cytosine; examples are benzoylurea/benzoyleneurea, and acetylurea/hydantoin. However even in cyclic molecules containing CO and NH groups, *e.g.*, anhydroglycine I, 3,6-dioxohydro-1,2,4,5-tetrazine II, 2,3-dihydroxyquinoxaline III and phthalazine-2,4-dione IV, binding



I II III IV

was not observed with these bases. This indicates that the atomic arrangement required for binding with adenine and cytosine would be cyclic alternant –CONH– groups. It should be noted that uracil[11] and thymine are regarded as typical members of category 5. In such a system, the proton donor and acceptor groups will be in the proper orientation with those in the bases to reinforce individual hydrogen bonds. In fact, the hydrogen bond system in the adenine-phenobarbital complex solved by Kim and Rich[13] is just the case as shown in Fig. 3.

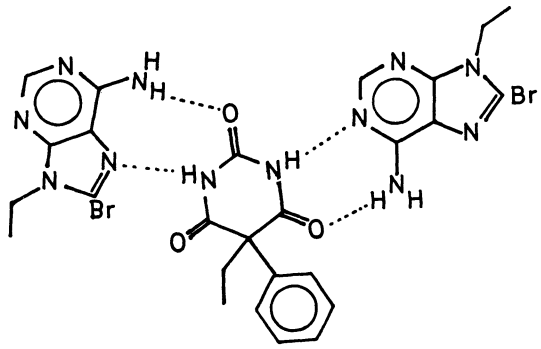


Fig. 3. The hydrogen bonding system of the complex crystal between phenobarbital and 8-bromo-9-ethyladenine, by Kim and Rich.

There are some other compounds which also bind with adenine and cytosine: 1-(2*H*)-phthalazinone, cycloserine, and 4,6-dihydroxy-1-mercaptopyrimidine. However, it is difficult to recognize any common features among them.

Amino and Nitrogen Heterocycles: A few compounds were found to bind with uracil and/or thymine; these are 1,3,5-triamino-2,4,6-triazine, azaadenine, and bromouracil. But many other related compounds, such as 2-methyl-4-amino-5-carbinopyrimidine, 2-aminopyridine, 2-aminopyrimidine, and 3-amino-1,2,4-triazole, do not form complexes.

We thank Professor Yoshio Sasada of Tokyo Institute of Technology for his valuable discussions and suggestions.

11) The complex of cytosine-uracil was found in this survey and its structure was determined by means of single crystal analysis.[10] The non-Watson-Crick pairing of uracil-cytosine found is almost the same as that of 5-fluorouracil-cytosine complex reported by Voet and Rich.[12]

12) D. Voet and A. Rich, *J. Amer. Chem. Soc.*, **91**, 3069 (1969).
13) S. Kim and A. Rich, *Proc. Natl. Acad. Sci. U.S.*, **60**, 402 (1969).