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The Crystal Structure of the Aluminum Hydride–N,N,N′,N′-Tetramethylethylenediamine Adduct

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The aluminum hydride-*N,N,N′,N′*-tetramethylethylenediamine adduct crystallizes as clear, colorless, needle-like orthorhombic crystals. The cell dimensions are:

$$a = 9{\cdot}554 \pm 0{\cdot}004,\ b = 17{\cdot}241 \pm 0{\cdot}009,\ c = 11{\cdot}866 \pm 0{\cdot}006\ \text{Å}\,.$$

The space group is $P2_12_12_1$ and there are eight formula weights per unit cell. A total of 2300 reflections was measured with the use of a proportional counter and copper radiation. The structure was refined by least-squares methods to a final residual R of 6·4%.

The crystal is composed of infinite chains of alternating aluminum hydride and diamine units. The aluminum atom is pentacoordinated with three hydrogen atoms (in the equatorial plane) and two nitrogen atoms at the corners of a trigonal bipyramid. The bidentate diamine unit is in the *trans* configuration.

Introduction

Recently an interest has arisen in the amine adducts of both aluminum hydride (or alane) and trimethylaluminum. The increased activity in this area has produced a number of interesting compounds in which aluminum apparently has fivefold coordination. The only direct evidence available for this unusual coordination for aluminum is the crystal structure determination of bis-trimethylamine alane by Heitsch, Nordman & Parry (1963). Unfortunately, there was disorder in the crystal and the structure could not be determined with high precision.

The Chemistry Division of the Naval Ordnance Laboratory, Corona, California has prepared a number of amine and substituted hydrazine adducts of both trimethylaluminum and alane. Since a number of these compounds were readily available, we decided to investigate the structures of several of the adducts. The final goals were: a better understanding of the bonding in these adducts, elucidation of the apparent fivefold coordination for aluminum, and a precise determination of the aluminum–nitrogen bond distance under varying conditions.

The following is a study of the structure of the *N,N,N′,N′*-tetramethylethylenediamine–alane adduct,

$$[(CH_3)_2N\text{–}CH_2\text{–}CH_2\text{–}N(CH_3)_2]\text{–}AlH_3\,.$$

This compound was first prepared by Davidson & Wartik (1960). They proposed a hydrogen-bridged dimer for the structure of the adduct in which the aluminum was six-coordinate. This proposal made it unnecessary to invoke fivefold coordination for the aluminum. The structure proposed by Davidson & Wartik (1960) is actually only one of several possible isomers. The structure of this compound appeared to be of definite interest and thus was chosen for further study.

Experimental

The adduct was prepared by repeated treatment of bis-trimethylamine alane with *N,N,N′,N′*-tetramethylethylenediamine. Because of the reactive nature of the alane adducts, all operations were carried out in a standard vacuum apparatus. The adduct sublimes readily, and clear prismatic crystals formed on the sides of the sealed and evacuated sample tube. The sample tube was opened in a glove box in an atmosphere of dry nitrogen and several small crystals were transferred to Lindemann-glass capillaries. The open ends of the capillaries were covered with stopcock grease. The capillaries were removed from the glove box and immediately sealed by fusing the glass below the grease-covered ends.

Weissenberg photographs of one of the crystals indicated that the crystals are orthorhombic. The systematic absences observed for a crystal rotating about what was later called the a axis were:

hkl	no absences
$0k0$	absent when $k = 2n+1$
$00l$	absent when $l = 2n+1$

The possible space groups are thus $P22_12_1$ (D_2^3) or $P2_12_12_1$ (D_2^4).

The unit-cell dimensions and intensity measurements were carried out by means of a General Electric single-crystal orienter with copper radiation ($\alpha_1 = 1{\cdot}54051$ and $\alpha_2 = 1{\cdot}54433$ Å). The unit-cell dimensions were determined by using a narrow beam with a narrow slit at the counter window. The averages of these measurements are given below:

$$a = 9{\cdot}554 \pm 0{\cdot}004,\ b = 17{\cdot}241 \pm 0{\cdot}009,$$
$$c = 11{\cdot}866 \pm 0{\cdot}006\ \text{Å}\ .$$

The density calculated for eight formula weights per unit cell is 1·01 g.cm^{-3}, a reasonable value for a substance of this type. The experimental density could not be determined because of the reactive nature of the compound.

A survey of the $h00$ reflections using the goniostat indicated that they were absent if $h = 2n+1$. Therefore, the most probable space group appeared to be $P2_12_12_1$ (D_2^4).

The crystal used for the intensity measurements was approximately 0·4 mm by 0·2 mm by 0·2 mm. A proportional counter and reverter (a simple pulse-height selector) were employed in measuring the intensity of 2300 reflections with $2\theta \leq 150{\cdot}0°$. Of these, 2269 were greater than 1·1 times the background and were regarded as observed reflections. The experimental details have been described more fully elsewhere by the author (Palenik, 1963).

Determination of the structure

Three three-dimensional Patterson syntheses were computed: (1) a sharpened synthesis with the origin peak intact, (2) a sharpened synthesis with the origin peak removed and (3) a synthesis with no sharpening and the origin peak intact. The Harker sections for the second synthesis were plotted and carefully studied. Several peaks were consistent with the three Harker sections, but two in particular were quite outstanding. A comparison of the origin peak in the third synthesis with these Harker peaks indicated that they were possible Al–Al interactions. Using these two peaks, the vectors between non-equivalent aluminum atoms were also located in the second synthesis.

One aluminum atom had x approximately equal to 0, while the other aluminum atom had z approximately equal to $\frac{1}{4}$. It appeared that any superpositions using only equivalent aluminum atoms would retain a false mirror plane in the resulting minimum function. Therefore, three superpositions were carried out; one on an Al(1)–Al(1′) vector, one on an Al(1)–Al(2) vector, and the last on an Al(1)–Al(2′) vector. The two diamine molecules were easily located in the resulting minimum function.

Refinement of the structure

The first Fourier synthesis was computed from all 2269 observed reflections, the phases being calculated with the use of the contribution of all eighteen of the heavier atoms. The scattering factors for neutral aluminum from Tomiie & Stam (1958), for nitrogen and carbon from Hoerni & Ibers (1954), and for hydrogen from McWeeny (1951) were used in this and all subsequent computations. The usual residual R (after adjustment of the scale factor) was 27·0%. A second set of positional parameters was obtained by the method described by Booth (1948). A second Fourier synthesis was calculated and a third set of positional parameters was obtained in the same way.

Least-squares refinement was started with the third set of parameters. Individual isotropic thermal parameters were used for each atom, and the full matrix was computed for each cycle. The function minimized was $\Sigma w \Delta F^2$ where the weighting scheme was:

$$\begin{array}{lll} \text{if} & F(\text{obs}) < 40, & \sqrt{w} = F(\text{obs})/40; \\ \text{if} & F(\text{obs}) > 200, & \sqrt{w} = 200/F(\text{obs}); \\ \text{if } 40 \leq & F(\text{obs}) \leq 200, & \sqrt{w} = 1{\cdot}0 \end{array}$$

where the limits 40 and 200 are on the scale used in Table 3. The above weighting scheme reflects our prejudice regarding the accuracy of the values of F(obs) and was used in all least-squares calculations. Four cycles of least-squares refinement dropped the

Table 1. *Probable hydrogen positions*

The hydrogen atom is given followed by the atom to which it is bonded, the position parameters times 10^3, the bond distance, and the peak height on the second difference map

Atom	x	y	z	Distance (Å)	Peak height (e.Å^{-3})
H(1) –Al(1)	−068	229	144	1·61	0·3
H(2) –Al(1)	088	279	329	1·60	0·3
H(3) –Al(1)	123	156	310	1·50	0·3
H(4) –Al(2)	021	094	−239	1·68	0·4
H(5) –Al(2)	080	−068	−197	1·65	0·3
H(6) –Al(2)	−120	028	−066	1·61	0·3
H(7) –C(1)	428	235	176	1·03	0·4
H(8) –C(1)	322	289	258	0·98	0·5
H(9) –C(1)	333	206	263	0·86	0·4
H(10)–C(2)	271	299	004	1·01	0·4
H(11)–C(2)	101	291	016	1·00	0·4
H(12)–C(2)	165	329	078	0·80	0·2
H(13)–C(3)	257	−014	086	0·94	0·4
H(14)–C(3)	120	−035	096	0·99	0·3
H(15)–C(3)	201	−066	−008	0·96	0·3
H(16)–C(4)	294	082	−180	0·92	0·4
H(17)–C(4)	314	005	−152	0·83	0·4
H(18)–C(4)	366	057	−078	0·84	0·5
H(19)–C(5)	275	120	159	1·10	0·5
H(20)–C(5)	338	163	040	0·99	0·5
H(21)–C(6)	104	149	−051	0·88	0·4
H(22)–C(6)	044	120	029	0·93	0·3
H(23)–C(7)	−049	183	487	0·81	0·3
H(24)–C(7)	−171	204	517	0·76	0·3
H(25)–C(7)	−057	248	519	0·99	0·3
H(26)–C(8)	−209	314	348	1·03	0·3
H(27)–C(8)	−276	273	252	0·96	0·4
H(28)–C(8)	−345	256	396	1·10	0·3
H(29)–C(9)	−252	−072	202	0·90	0·3
H(30)–C(9)	−170	−019	298	0·93	0·3
H(31)–C(9)	−143	−021	173	0·90	0·4
H(32)–C(10)	−463	048	111	0·87	0·4
H(33)–C(10)	−431	−020	086	0·82	0·4
H(34)–C(10)	−331	046	045	1·02	0·5
H(35)–C(11)	−284	110	402	0·84	0·4
H(36)–C(11)	−150	090	371	0·98	0·3
H(37)–C(12)	−223	127	187	0·89	0·5
H(38)–C(12)	−369	133	226	0·93	0·4

Table 2. *Final positional and thermal parameters and the estimated standard deviations for the heavier atoms*

All values have been multiplied by 10^4. The temperature factor for an atom is of the form

$$\exp\left[-(\beta_{11}h^2+\beta_{22}k^2+\beta_{33}l^2+\beta_{12}hk+\beta_{13}hl+\beta_{23}kl)\right]$$

	x	y	z	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
Al(1)	0236	2144	2457	0089	0018	0047	−0011	−0004	−0001
Al(2)	−0043	0124	−1630	0081	0018	0054	−0007	−0002	−0015
σ	0001	0001	0001	0001	0001	0001	0001	0002	0001
N(1)	2106	2235	1396	0086	0016	0043	−0009	−0010	−0002
N(2)	1696	0429	−0510	0079	0019	0047	0002	−0007	−0012
N(3)	−1636	2024	3577	0113	0024	0046	−0026	0017	−0010
N(4)	−3294	0237	2200	0084	0018	0056	−0009	0009	0006
σ	0004	0002	0003	0004	0001	0003	0004	0006	0003
C(1)	3311	2422	2128	0090	0031	0088	−0030	−0032	−0024
C(2)	1916	2873	0578	0136	0022	0062	−0015	0050	0019
C(3)	1830	−0191	0336	0167	0027	0086	−0017	−0076	0021
C(4)	2979	0471	−1205	0083	0039	0067	−0005	−0004	−0038
C(5)	2500	1498	0797	0082	0025	0063	0001	−0003	−0022
C(6)	1355	1186	0021	0086	0021	0060	0003	−0045	−0020
C(7)	−1149	2117	4738	0219	0065	0040	−0098	0006	−0011
C(8)	−2642	2641	3308	0136	0032	0117	0016	0082	−0013
C(9)	−2071	−0290	2270	0096	0032	0122	0017	0062	0011
C(10)	−3890	0189	1059	0142	0037	0051	−0022	−0006	−0001
C(11)	−2293	1243	3510	0142	0029	0060	−0049	0023	0019
C(12)	−2850	1065	2350	0101	0023	0060	−0019	0003	0022
σ	0006	0003	0005	0007	0002	0004	0006	0010	0005

residual R from 22·9 to 11·7% and the weighted sum of the residuals from 17751·3 to 7318·5.

Anisotropic thermal parameters were introduced at this point, and the full matrix was approximated by 3×3 blocks for positional parameters and with 6×6 blocks for the thermal parameters. Partial shifts of 0·75 and 0·50 were used for the positional and thermal parameters, respectively. Since the isotropic refinement had included the interaction between scale and temperature factors, the scale factor (G) was shifted by 0·25 of the amount calculated by dividing $\Sigma w\Delta F(\partial|F_c|/\partial G)$ by $\Sigma w(\partial|F_c|/\partial G)^2$. Three cycles reduced R to 8·9% and $\Sigma w\Delta F^2$ to 4299·9. At this point it seemed reasonable to include the contribution of the 38 hydrogen atoms in the calculation.

A difference Fourier synthesis was calculated and used as a guide to locating the hydrogen atoms. It was assumed that hydrogen atoms bonded to carbon atoms would surround the atom tetrahedrally with an average C–H distance of 1·0 Å. In the case of hydrogen atoms bonded to aluminum atoms, the only assumption was that the Al–H distance would be about 1·5 Å. The hydrogen atoms were all placed in high positive areas in the difference map using the above assumptions. In the majority of the cases, the hydrogen atoms appeared as resolved peaks.

The hydrogen atoms were included in the structure factor calculation for the subsequent least-squares calculations, but their positional and thermal parameters (isotropic B of 6·0) were not refined. Six least-squares cycles using the block approximation were calculated followed by one cycle in which the entire 163×163 matrix was computed.

A second difference Fourier synthesis was calculated and a final set of hydrogen positions was obtained. These hydrogen atom positions together with their approximate peak heights are given in Table 1. The distance of each hydrogen atom from the atom to which it is bonded is also given in Table 1. One additional least-squares cycle was computed using the full matrix. The final parameters for the heavier atoms are given in Table 2. The standard deviations were obtained from the inverse of the full matrix; the individual values for a given type of atom were averaged and are given in Table 2. The structure factors computed with the parameters given in Tables 1 and 2 are presented in Table 3. The final residual R is 6·4% for the observed reflections.

Results and discussion

While there are 18 independent non-hydrogen atoms in the asymmetric unit of this structure, there are only four chemically distinct types of intramolecular distances: (1) Al–N, (2) N–CH_3, (3) N–CH_2–, and (4) –CH_2–CH_2–. The various intramolecular distances have been calculated and are tabulated in Table 4. In addition the atomic numbering and the distances are illustrated in Fig. 1. The agreement between chemically equivalent distances is good.

The average of the two C–C single bonds is 1·517 ± 0·010 Å, not significantly different from the value of 1·533 ± 0·003 Å suggested by Bartell (1959) for a C–C single bond. Wright & Marsh (1962) found that the average C–C single bond in L-lysine monohydrochloride monohydrate was 1·524 ± 0·003 Å, also in agreement with our value.

The twelve N–C bonds can be divided into two classes, the N–CH_3 bonds and the N–CH_2– bonds.

Table 3. *Observed and calculated structure factors*

The five columns in each group contain the values, reading from left to right, of k, $10F_o$, $10,F_c,$, $10A_c$, $10B_c$
A negative F_o indicates an unobserved reflection which was not included in the least-squares refinement

H= 0,L= 0				
2	85	26	26	-0
4	1497	1764	1764	-0
6	202	199	199	-0
8	609	575	575	-0
10	381	373	373	-0
12	494	487	-487	0
14	228	203	203	-0
16	257	241	-241	0
18	96	99	99	0
20	73	68	-68	0
H= 0,L= 1				
1	359	353	0	353
2	688	702	-702	-0
3	513	520	0	520
4	754	779	779	-0
5	216	182	0	182
6	90	72	72	0
7	201	206	0	206
8	679	662	662	-0
9	350	323	0	323
10	290	259	-259	-0
11	83	87	0	87
12	199	185	185	-0
13	19	4	0	-4
14	114	101	101	-0
15	69	70	0	70
16	21	12	12	-0
17	82	73	0	-73
18	158	171	171	-0
19	133	60	0	60
20	71	62	-62	0
21	23	20	0	20
H= 0,L= 2				
0	601	595	-595	-0
1	318	334	-0	-334
2	199	192	192	0
3	141	113	-0	-113
4	534	552	-552	-0
5	43	39	0	-39
6	242	210	210	-0
7	19	3	0	-3
8	269	252	-252	0
9	63	19	0	19
10	274	253	-253	0
11	157	167	0	-167
12	17	10	10	0
13	164	164	-0	164
14	104	110	-110	0
15	226	230	0	-230
16	117	128	128	-0
17	21	18	-0	-18
18	22	29	-29	0
19	89	88	-0	-88
20	48	50	50	0
21	10	9	-0	-9
H= 0,L= 3				
1	111	135	0	135
2	202	205	205	-0
3	96	111	0	111
4	98	111	111	-0
5	492	490	-0	-490
6	550	513	513	-0
7	244	244	-0	-244
8	177	213	-213	-0
9	241	239	0	-239
10	278	269	269	-0
11	143	132	-0	-132
12	14	1	1	-0
13	299	290	-0	-290
14	29	23	-23	-0
15	289	296	-0	-296
16	28	22	-22	0
17	110	119	-0	-119
18	103	106	-106	-0
19	148	140	-0	-140
20	107	104	104	-0
21	73	82	-0	-82
H= 0,L= 4				
0	232	233	233	0
1	145	122	-0	122
2	265	287	-287	0
3	241	241	0	241
4	38	52	-52	0
5	55	40	0	-40
6	274	236	-236	0
7	605	600	0	600
8	68	67	-67	-0
9	27	26	0	26
10	110	111	111	0
11	331	320	0	320
12	246	248	-248	0
13	108	106	0	106
14	29	49	-49	0
15	168	171	0	171
16	183	184	-184	-0
17	20	22	0	22
18	33	30	30	-0
19	18	1	-0	1
20	63	61	-61	0
H= 0,L= 5				
1	58	26	0	-26
2	25	24	-24	0
3	36	60	0	60
4	69	67	67	-0
5	74	80	-0	-80
6	31	52	-52	0
7	241	212	-0	-212
8	69	80	80	-0
9	28	22	0	22
10	120	121	-121	0
11	141	132	0	132
12	30	41	-41	-0
13	116	111	-0	111
14	205	200	-200	0
15	33	26	0	-26
16	78	93	-93	0
17	81	80	0	80
18	37	39	-39	0
19	56	56	0	56
20	128	139	-139	0
H= 0,L= 6				
0	17	26	26	-0
1	247	261	0	261
2	106	136	136	-0
3	101	106	0	106
4	63	56	56	0
5	-22	19	0	-19
6	82	101	101	-0
7	186	178	0	178
8	290	272	272	-0
9	59	55	-0	55
10	107	94	94	-0
11	96	100	0	100
12	200	201	201	-0
13	44	52	0	-52
14	46	45	-45	0
15	-22	22	0	22
16	242	237	237	-0
17	17	6	0	-6
18	21	12	-12	0
19	28	18	-0	-18
H= 0,L= 7				
1	298	318	0	-318
2	225	227	227	0
3	75	88	0	88
4	51	56	-56	0
5	-23	8	0	8
6	381	378	378	-0
7	35	28	-0	-28
8	54	42	-42	-0
9	34	38	0	38
10	389	374	374	-0
11	-24	20	0	-20
12	72	72	72	0
13	67	72	0	72
14	172	178	178	-0
15	20	9	0	9
16	142	137	137	-0
17	44	32	0	32
18	15	14	14	-0
19	103	126	0	126
H= 0,L= 8				
0	314	311	311	0
1	455	486	-0	-486
2	271	263	-263	0
3	153	145	-0	-145
4	22	20	20	0
5	310	303	-0	-303
6	134	125	-125	0
7	145	147	-0	-147
8	18	24	-24	0
9	211	201	-0	-201
10	197	183	183	0
11	64	30	-0	-30
12	213	219	-219	0
13	-22	6	0	6
14	86	83	83	0
15	50	55	-0	-55
16	55	47	-47	-0
17	52	53	0	53
18	70	80	80	0
H= 0,L= 9				
1	108	112	0	112
2	175	172	-172	0
3	23	10	0	-10
4	294	308	308	-0
5	17	23	-0	-23
6	214	213	-213	0
7	185	185	0	-185
8	377	395	395	-0
9	11	2	-0	-2
10	162	167	-167	-0
11	12	11	0	11
12	68	61	61	0
13	32	20	0	-20
14	70	69	69	-0
15	98	83	-0	-83
16	14	1	-1	-0
17	20	21	0	-21
H= 0,L=10				
0	404	411	-411	0
1	211	205	0	205
2	131	148	148	-0
3	213	206	-0	206
4	228	236	-236	0
5	155	142	0	142
6	13	9	-9	-0
7	70	69	0	69
8	9	11	11	0
9	179	183	0	183
10	182	178	-178	0
11	53	52	0	52
12	149	136	136	-0
13	21	6	-0	6
14	184	164	-164	0
15	60	54	0	-54
16	57	74	74	0
H= 0,L=11				
1	52	55	-0	-55
2	73	68	68	-0
3	70	71	-0	71
4	119	119	-119	0
5	143	147	-0	-147
6	19	22	-22	0
7	32	30	-0	30
8	134	135	-135	0
9	39	34	0	34
10	9	1	1	0
11	42	34	0	34
12	114	110	-110	0
13	40	35	0	35
14	81	86	-86	0
H= 0,L=12				
0	133	137	137	-0
1	44	45	-0	45
2	36	36	-36	-0
3	53	61	0	61
4	15	2	2	0
5	-22	2	0	2
6	62	61	61	-0
7	80	75	0	75
8	104	99	99	-0
9	27	15	-0	-15
10	135	121	121	-0
11	38	45	0	45
12	-15	8	-8	-0
H= 0,L=13				
1	71	70	0	70
2	41	47	-47	0
3	22	18	0	-18
4	49	46	46	-0
5	23	12	0	-12
6	65	51	-51	0
7	20	25	0	-25
8	96	89	89	0
9	13	8	0	8
10	-15	0	0	0
H= 0,L=14				
0	11	17	-17	-0
1	11	16	-0	16
2	16	18	-18	0
3	49	48	0	-48
4	89	83	-83	0
5	37	36	-0	-36
6	-15	8	-8	0
7	80	78	-0	-78
H= 1,L= 0				
1	132	115	-0	-115
2	469	424	0	424
3	44	34	0	34
4	547	564	-0	-564
5	124	105	-0	-105
6	339	325	0	325
7	78	79	-0	-79
8	400	372	-0	-372
9	240	232	-0	-232
10	348	342	0	342
11	296	300	-0	-300
12	31	6	0	6
13	226	224	0	224
14	36	29	-0	29
15	103	106	-0	-106
16	161	159	0	159
17	120	125	0	125
18	13	10	-0	-10
19	16	6	-0	6
20	184	179	0	179
21	95	94	-0	94
H= 1,L= 1				
0	47	62	-0	-62
1	278	247	224	103
2	1088	1166	-654	-965
3	672	685	336	597
4	186	167	52	-159
5	113	153	-151	18
6	336	309	95	-293
7	310	299	299	20
8	416	406	8	-406
9	128	95	85	41
10	121	98	-67	71
11	179	183	36	179
12	425	405	141	-379
13	84	78	30	71
14	240	239	137	180
15	113	107	2	-107
16	215	206	97	-182
17	73	79	65	45
18	113	107	65	85
19	14	4	-0	-4
20	46	39	37	-13
21	34	37	-1	37
H= 1,L= 2				
0	670	694	-694	0
1	930	984	164	973
2	1207	1248	1246	76
3	541	556	183	524
4	290	300	-11	300
5	338	338	195	-276
6	385	377	131	-354
7	611	600	304	517
8	358	321	-223	230
9	260	251	234	-90
10	224	206	-120	-167
11	265	258	257	22
12	67	60	32	51
13	305	312	212	-229
14	195	196	-166	-105
15	157	162	139	-83
16	174	178	11	-177
17	20	168	163	-42
18	46	51	-20	46
19	83	80	74	-30
20	155	146	21	-145
21	89	99	93	-31
H= 1,L= 3				
0	171	156	0	-156
1	61	48	-47	-10
2	106	124	124	-2
3	189	204	-180	96
4	227	245	-97	-225
5	630	629	-405	481
6	244	220	211	-61
7	329	280	-81	268
8	176	147	-140	44
9	226	226	-196	113
10	110	109	64	-88
11	160	151	-147	35
12	177	160	-59	149
13	192	191	-191	-8
14	175	176	-39	-171
15	113	116	-70	-93
16	126	128	60	112
17	51	51	-12	50
18	80	82	-14	-81
19	54	52	-31	-42
20	24	23	21	10
21	29	25	3	-25
H= 1,L= 4				
0	122	106	-106	-0
1	120	140	-72	-120
2	283	273	-197	189
3	122	118	10	-118
4	253	258	136	-219
5	109	99	-41	-90
6	328	312	-273	151
7	132	120	-24	117
8	290	295	10	-294
9	115	130	-125	37
10	172	155	-128	86
11	153	157	-132	84
12	180	178	-32	-174
13	176	179	-164	-72
14	148	143	-78	-120
15	161	173	-103	139
16	105	102	95	-37
17	115	122	-121	9
18	145	141	20	-139
19	77	73	-72	-9
20	47	41	8	40
H= 1,L= 5				
0	406	404	0	404
1	385	381	272	-267
2	133	123	121	-20
3	280	267	176	200
4	416	429	50	426
5	192	160	73	143
6	175	202	53	195
7	106	129	123	38
8	195	190	96	164
9	134	124	90	85
10	313	316	11	316
11	50	47	32	33
12	36	38	-36	-13
13	124	124	-23	121
14	249	265	55	259
15	38	35	35	-4
16	73	73	11	-72
17	45	46	-5	-45
18	96	90	-31	85
19	40	35	5	35
20	30	31	-16	-26
H= 1,L= 6				
0	192	174	174	-0
1	125	106	31	101
2	111	118	87	79
3	162	160	48	152
4	233	246	-100	224
5	111	115	110	-33
6	76	81	3	-81
7	40	39	39	-2
8	313	306	-16	306
9	197	179	115	137
10	97	93	27	89
11	58	49	-39	30
12	280	283	-109	261
13	45	48	44	-20
14	110	121	-40	114
15	97	99	-37	-91
16	78	81	-37	72
17	51	49	-15	47
18	193	176	-19	175
19	42	41	-21	-36
H= 1,L= 7				
0	275	307	-0	-307
1	172	183	163	82
2	202	209	-207	25
3	203	211	183	-104
4	266	283	102	-264
5	66	74	58	45
6	76	84	-66	-52
7	214	213	211	30
8	213	211	209	-28
9	150	149	141	47
10	183	190	-161	-101
11	67	79	78	-7
12	97	101	-71	72
13	73	86	76	-41
14	108	148	61	-135
15	45	35	-0	35
16	72	69	-30	63
17	66	59	58	6
18	54	53	-20	-48
H= 1,L= 8				
0	365	358	-358	0
1	111	115	88	-74
2	126	123	-41	116
3	41	34	-25	-25
4	325	335	-148	-300
5	58	57	50	26
6	131	122	-26	120
7	157	165	118	-115
8	315	326	-75	-317
9	76	71	10	70
10	177	174	-150	87
11	132	139	128	-53
12	151	140	97	-103
13	19	30	9	29
14	65	63	17	-60
15	103	94	93	14
16	68	62	55	24
17	56	56	53	19
18	57	71	-6	-71
H= 1,L= 9				
0	292	292	0	292
1	284	284	-261	111
2	263	268	30	-266
3	318	327	-312	97
4	171	177	89	152
5	180	194	-185	-62
6	85	81	-23	-77
7	187	193	-190	37
8	107	109	86	-66
9	63	56	-43	35
10	85	90	-15	88
11	88	91	-87	24
12	179	173	72	-157
13	47	45	-43	-13
14	89	89	13	87
15	46	43	10	-42
16	94	99	5	-98
17	32	44	-9	43
H= 1,L=10				
0	69	71	71	-0
1	14	8	6	-6
2	168	164	136	-92
3	140	144	-17	-143
4	86	85	-42	74
5	103	105	-35	-99
6	264	264	45	-260
7	41	37	-23	29
8	51	56	16	53
9	64	67	-37	55
10	157	160	-40	-155
11	38	36	-35	7
12	13	7	0	-7
13	69	62	-18	-59
14	79	72	-41	-59
15	69	73	-48	54
H= 1,L=11				
0	14	13	0	-13
1	40	43	31	29
2	227	229	9	229
3	16	22	-3	-22
4	38	34	-34	5
5	37	42	-20	36
6	171	179	138	113
7	120	116	37	110
8	93	87	-31	81
9	18	22	17	12
10	28	24	24	4
11	54	47	23	40
12	139	125	-65	107
13	29	30	-28	-9
14	39	50	-28	-42
H= 1,L=12				
0	43	48	48	0
1	41	45	43	-13
2	132	134	-112	74
3	88	95	-65	-69
4	36	36	19	-31
5	25	24	17	17
6	123	122	8	121
7	27	19	-0	19
8	30	26	4	-26
9	41	34	-19	28
10	147	140	22	138
11	-16	14	12	6
12	43	46	-29	35
H= 1,L=13				
0	34	35	0	35
1	86	85	76	37
2	139	130	-34	-126
3	86	86	32	-79
4	66	57	57	4
5	99	85	83	22
6	87	77	32	-70
7	66	62	23	-58
8	51	51	11	-49
9	76	79	79	3
10	29	33	-33	-2
H= 1,L=14				
0	26	29	-29	0
1	29	20	-2	-20
2	24	23	-17	-16
3	37	33	20	-26
4	49	44	3	44
5	37	33	15	-30
6	82	80	-3	-80
7	25	29	29	1
H= 2,L= 0				
0	1228	1354	-1354	-0
1	34	20	-20	0
2	127	101	101	-0
3	449	430	-430	0
4	266	196	196	-0
5	55	63	-63	0
6	310	301	301	-0
7	63	70	-70	0
8	97	59	-59	-0
9	288	242	-242	0
10	401	407	407	-0
11	223	223	-223	0
12	151	149	149	-0
13	17	11	11	0
14	292	292	292	-0
15	59	62	-62	0
16	34	26	26	0
17	94	105	105	0
18	70	75	75	-0
19	62	65	-65	0
20	-17	1	-1	0
21	42	46	46	-0
H= 2,L= 1				
0	1048	1149	0	1149
1	364	369	-276	-245
2	207	203	203	12
3	321	308	-301	66
4	308	280	154	233
5	58	42	-39	16
6	527	540	-528	113
7	196	151	-145	-41
8	253	251	250	18
9	81	109	-74	78
10	170	174	53	168
11	157	160	-9	160
12	359	357	278	-224
13	191	182	-18	181
14	143	139	138	14
15	59	62	35	51
16	89	87	77	-42
17	177	177	32	174
18	185	191	190	19
19	90	80	-13	79
20	45	41	31	-27
21	68	80	62	50
H= 2,L= 2				
0	254	201	-201	0
1	224	214	-21	-213
2	245	238	97	-218
3	233	217	-38	-213
4	281	266	-266	-9
5	396	385	103	-371
6	348	317	-211	-236
7	409	361	208	-295
8	153	137	122	61
9	277	257	6	-257
10	202	206	-159	-128
11	193	188	138	-127
12	164	161	144	-71
13	290	290	59	-283
14	302	306	-306	-20
15	176	178	168	58
16	131	136	126	-51
17	35	37	4	-37
18	92	92	-90	-20
19	51	40	27	30
20	25	27	3	-26
21	9	17	7	-15
H= 2,L= 3				
0	376	397	0	397
1	238	252	-18	-252
2	108	101	101	-12
3	387	389	-388	30
4	503	495	-490	67
5	85	72	65	-29
6	184	165	121	-112
7	224	236	-198	-125
8	248	243	-219	104
9	155	155	53	-145
10	189	179	136	-116
11	203	213	-56	-205
12	210	213	-211	-30
13	119	123	-86	-88
14	69	71	34	-62
15	114	104	42	-95
16	112	116	110	35
17	149	152	-74	-132
18	69	69	-66	20
19	113	101	71	-72
20	64	63	63	1
H= 2,L= 4				
0	240	232	232	0
1	404	417	-153	388
2	814	831	-807	197
3	496	516	-315	408
4	107	108	-71	81
5	276	308	42	305
6	367	359	-274	231
7	78	54	-53	-8
8	225	234	-223	79
9	205	209	20	207
10	131	129	-25	127
11	202	198	-197	26
12	301	304	-298	60
13	89	93	86	37
14	211	223	223	-1
15	74	76	44	-62
16	118	123	-119	29
17	53	47	33	33
18	41	90	82	-37
19	24	20	6	-19
20	25	30	-22	20
H= 2,L= 5				
0	94	102	-0	102
1	105	118	-0	118
2	249	255	-237	92
3	65	67	67	-0
4	280	287	247	-144
5	94	107	24	104
6	510	536	-536	-0
7	166	162	-58	151
8	165	165	165	-2
9	161	163	-116	114
10	443	443	-440	50
11	116	123	-113	48
12	124	111	-47	-100
13	52	48	41	-23
14	60	69	-65	-20
15	110	123	-55	109
16	199	201	-200	-11
17	36	36	36	-6
18	35	26	-8	25
19	35	33	-6	32
20	135	158	-155	-29
H= 2,L= 6				
0	35	43	43	0
1	281	270	178	-203
2	554	594	586	106
3	108	105	-54	-90
4	26	21	19	-9
5	142	157	136	78
6	382	392	352	173
7	212	199	159	-120
8	178	175	173	19
9	93	86	-34	79
10	60	62	-6	62
11	125	144	139	-35
12	238	239	236	-39
13	86	102	-17	100
14	86	95	-90	-28
15	99	94	89	30
16	76	76	75	-12
17	37	31	-6	31
18	61	59	-57	-13
19	50	56	-19	53
H= 2,L= 7				
0	85	85	0	85
1	212	214	172	127
2	286	267	37	-264
3	94	119	-28	116
4	95	89	-71	-52
5	139	157	151	-40
6	243	270	257	-84
7	136	141	-135	41
8	68	63	-28	57
9	158	153	67	138
10	173	168	162	45
11	128	135	-111	76
12	33	44	39	-19
13	91	105	-30	100
14	53	50	49	5
15	48	45	-15	42
16	149	136	124	57
17	99	97	-30	92
18	-16	7	4	6
H= 2,L= 8				
0	83	86	86	-0
1	93	77	-18	-75
2	257	262	-262	4
3	188	196	-2	-196
4	200	201	79	185
5	276	279	37	-276
6	63	59	-45	38
7	122	126	121	-35
8	205	211	-86	192
9	144	153	-51	-144
10	62	65	22	61
11	92	101	-48	-89
12	111	114	-76	87
13	123	128	-43	-120
14	139	136	124	55
15	51	49	-31	-38
16	98	88	-85	24
17	42	43	-15	-41
H= 2,L= 9				
0	41	35	-0	35
1	29	21	8	-20
2	76	77	-40	65
3	77	90	-19	-88
4	97	87	73	-47
5	56	64	33	-55
6	147	150	-138	58
7	26	11	9	5
8	95	91	-0	91
9	134	138	-31	-135
10	74	85	-33	78
11	84	85	25	-81
12	65	58	54	21
13	170	159	-61	-146
14	30	18	-16	-9
15	38	37	29	-22
16	45	48	-47	11
H= 2,L=10				
0	107	99	-99	0
1	80	88	36	80
2	92	97	-17	-95
3	76	76	-67	35
4	156	156	-155	22
5	124	120	83	86
6	127	133	-84	-103
7	66	74	-1	74
8	44	47	-37	28
9	29	13	-13	0
10	100	103	-87	-56
11	55	49	-49	-3
12	56	47	-35	-31
13	85	75	-52	54
14	104	99	-97	19
15	51	50	0	50
H= 2,L=11				
0	120	125	-0	-125
1	67	69	-69	8
2	48	51	-36	36
3	90	93	-92	16
4	165	162	-135	-89
5	118	115	5	115
6	86	91	91	-6
7	59	56	-56	5
8	197	186	-182	40
9	45	50	36	35
10	32	33	-14	-30
11	36	21	-13	16
12	123	120	-107	53
13	62	62	39	47
14	33	43	-40	-14
H= 2,L=12				
0	235	227	227	-0
1	79	76	-68	34
2	46	40	39	8
3	92	82	30	77
4	238	234	233	-19
5	14	16	15	-5
6	51	49	45	-15
7	89	80	49	63
8	33	23	16	-16
9	22	23	20	13
10	85	83	82	6
11	45	45	-15	42
12	35	41	-36	15
H= 2,L=13				
0	35	25	0	25
1	52	43	-39	20
2	54	44	-26	-35
3	22	14	9	-11
4	139	127	117	-49
5	63	57	-26	50
6	78	69	-63	-27
7	43	41	21	35
8	117	116	116	4
9	20	20	-13	14
H= 2,L=14				
0	173	154	-154	0
1	123	111	12	-110
2	102	98	90	-38
3	96	91	-24	-87
4	57	57	-57	-0
5	48	46	6	-46
6	35	43	4	-42
H= 3,L= 0				
1	54	63	0	-63
2	231	208	0	208
3	202	181	0	-181
4	249	252	0	252
5	473	422	-0	-422
6	531	543	0	543
7	18	5	0	-5
8	263	228	0	228
9	131	135	-0	135
10	435	424	0	424
11	41	37	0	37
12	257	247	0	247
13	171	173	-0	-173
14	350	351	0	351
15	59	57	-0	57
16	258	267	0	267
17	11	8	-0	-8
18	75	79	0	79
19	54	52	-0	52
20	191	191	0	191
H= 3,L= 1				
0	-23	37	0	-37
1	241	252	75	-240
2	570	522	73	-516
3	79	94	-93	-10
4	133	143	140	-30
5	365	340	338	-35
6	350	364	-44	-361
7	216	202	-53	194
8	195	201	199	-32
9	190	179	171	51
10	138	115	23	-112
11	157	151	123	-88
12	168	157	-53	-148
13	111	110	97	51
14	49	47	39	-26
15	99	107	102	32
16	122	132	17	-131
17	45	43	-34	27
18	26	21	-13	17
19	57	48	38	-29
20	18	22	-10	-20
H= 3,L= 2				
0	469	484	484	-0
1	322	335	-81	-325
2	487	484	-275	-398
3	61	58	-55	18
4	125	121	40	-114
5	149	176	79	-157
6	358	349	15	-348
7	57	52	-18	49
8	195	217	214	39
9	93	96	70	-67
10	408	409	-46	-406
11	38	25	1	25
12	72	78	-8	-77
13	68	71	65	28
14	101	106	77	-73
15	120	129	129	9
16	35	40	-31	-25
17	106	98	35	92
18	26	19	13	14
19	136	130	119	-51
20	83	91	-40	-82
H= 3,L= 3				
0	731	764	-0	-764
1	864	885	-786	406
2	614	609	-303	528
3	465	472	-430	-193
4	371	372	-53	-368
5	302	287	-285	-34
6	132	135	-58	122
7	292	312	-307	-53
8	58	58	-26	-51
9	222	224	-212	-71
10	299	304	-167	-254
11	146	154	-124	94
12	173	171	-29	169
13	99	100	52	-85
14	186	191	40	-187
15	155	150	-61	137
16	124	122	-28	119
17	86	81	-27	-76
18	88	82	-27	-77
19	30	28	4	27
20	47	49	-38	30
H= 3,L= 4				
0	58	69	69	-0
1	355	360	150	327
2	279	276	192	198
3	214	213	-213	2
4	330	348	-33	-346
5	203	205	-123	164
6	384	366	156	331
7	230	222	-190	-114
8	350	358	-11	-358
9	245	249	-183	168
10	195	197	6	197
11	115	111	-48	-100
12	94	92	25	-89
13	107	113	-111	20
14	44	41	30	27
15	85	91	-66	-63
16	68	69	-61	32
17	68	70	-67	-20
18	115	110	-23	-108
19	84	85	-70	48
20	35	41	23	34
H= 3,L= 5				
0	877	867	0	867
1	45	40	34	20
2	203	222	-220	33
3	102	108	70	81
4	373	393	47	390
5	151	163	148	-68
6	103	92	-36	84
7	47	45	-7	44
8	65	66	6	65
9	167	168	112	125
10	224	227	-122	192
11	100	100	12	-99
12	144	154	25	-152
13	98	111	109	22
14	123	133	-31	129
15	66	64	-43	-47
16	50	55	7	-55
17	73	70	-6	69
18	94	91	-0	91
19	32	34	-17	-30
H= 3,L= 6				
0	228	210	-210	-0
1	117	123	-122	10
2	261	264	42	-261
3	111	113	-108	35
4	304	320	-37	317
5	355	367	-305	-202
6	143	153	23	-152
7	294	296	-106	276
8	410	401	-72	394
9	299	287	-242	-155
10	178	183	-70	-169
11	26	36	-29	21
12	127	138	54	126
13	78	84	-79	-26
14	107	107	-8	107
15	37	35	-10	33
16	68	63	30	55
17	39	36	28	22
18	120	127	-8	126
19	28	37	-12	-35
H= 3,L= 7				
0	402	419	-0	-419
1	124	125	107	63
2	140	64	8	64
3	177	190	177	-68
4	272	292	-9	-292
5	91	93	93	0
6	125	127	43	-119
7	105	102	102	-9
8	207	204	-128	-159
9	146	158	-72	-140
10	306	304	62	-297
11	106	114	104	48
12	42	37	-19	32
13	104	99	-11	-98
14	181	181	-5	-181
15	100	100	99	8
16	96	85	-11	84
17	75	72	13	-70
18	53	64	6	-64
H= 3,L= 8				
0	33	52	52	0
1	49	59	52	27
2	47	49	-37	33
3	106	108	-8	-108
4	37	34	12	31
5	142	141	133	-45
6	154	166	-92	138
7	36	35	16	32
8	55	51	40	-32
9	143	151	139	57
10	29	23	6	22
11	86	89	87	-14
12	98	94	-39	-85
13	141	138	137	-11
14	40	37	-28	-24
15	125	122	122	7
16	61	59	-13	-58
17	51	58	57	-10
H= 3,L= 9				
0	51	66	-0	-66
1	75	74	-29	-68
2	105	104	-53	-90
3	90	84	-15	-83
4	58	71	22	-68
5	73	72	-52	50
6	105	107	97	-44
7	121	120	-120	1
8	78	82	45	-68
9	23	129	-121	-40
10	20	10	8	5
11	115	112	-105	-38
12	95	88	-27	-83
13	64	62	-55	28
14	46	37	26	26
15	83	86	-85	-13
16	53	70	5	-70
H= 3,L=10				
0	123	129	-129	0
1	132	138	-121	-69
2	63	64	47	-46
3	35	31	15	27
4	85	92	28	87
5	108	97	-93	-28
6	28	25	12	-22
7	72	78	-78	-3
8	101	102	21	99
9	100	98	-89	-40
10	98	89	-8	-89
11	21	163	-161	22
12	42	34	32	-10
13	104	91	-88	24
14	46	41	-0	-41
15	83	106	-104	-20
H= 3,L=11				
0	29	27	-0	27
1	80	71	0	71
2	152	158	4	158
3	136	136	129	-40
4	64	68	-7	68
5	40	38	15	35
6	130	124	-3	124
7	63	63	60	-20
8	127	121	11	121
9	71	68	-67	-8
10	59	52	-22	47
11	81	70	-0	70
12	117	123	30	120
13	27	30	28	-13
H= 3,L=12				
0	16	20	-20	-0
1	58	48	39	26
2	93	92	83	40
3	50	50	40	-28
4	66	61	19	-58
5	32	32	22	23
6	132	129	21	127
7	81	71	24	-67
8	50	36	2	-36
9	58	58	1	58
10	66	76	17	74
11	28	44	38	-20
H= 3,L=13				
0	33	32	-0	32
1	111	97	82	-53
2	202	180	2	-180
3	84	72	51	51
4	42	35	-31	-17
5	106	93	87	-32
6	67	60	-18	-57
7	30	36	25	25
8	62	57	16	-54
9	54	58	57	13
H= 3,L=14				
0	20	23	-23	-0
1	59	56	-48	27
2	68	67	25	-63
3	52	54	42	33
4	55	58	-18	55
H= 4,L= 0				
0	565	512	512	-0
1	60	57	-57	0
2	78	74	-74	-0
3	180	172	172	-0
4	192	193	193	-0
5	161	121	121	0
6	48	59	59	-0
7	86	60	60	0
8	231	235	235	-0
9	209	172	172	0
10	160	145	145	-0
11	49	50	50	0
12	31	24	24	0
13	117	117	117	0
14	229	244	244	-0
15	12	3	-3	0
16	109	103	-103	0
17	44	46	-46	-0
18	114	111	111	-0
19	19	23	23	0
20	14	13	-13	-0
H= 4,L= 1				
0	352	359	0	-359
1	87	98	8	98
2	138	135	-133	22
3	259	257	163	-198
4	358	318	278	-154
5	221	242	-242	4
6	191	170	169	-23
7	189	195	149	126
8	355	355	355	-6
9	137	122	-105	-62
10	9	89	19	-87
11	87	81	80	14
12	272	268	237	125
13	-24	9	6	7
14	161	165	161	-37
15	167	182	-68	168
16	103	102	84	58
17	56	62	60	14
18	186	178	176	-26
19	36	39	-37	12
20	32	32	-20	25
H= 4,L= 2				
0	671	699	-699	0
1	392	399	285	-279
2	109	115	46	106
3	636	614	-348	-506
4	224	223	-218	-43
5	101	112	24	-109
6	114	95	64	70
7	380	367	-99	-353
8	153	157	-114	-108
9	243	248	-196	-151
10	249	240	-233	54
11	178	184	-36	-180
12	184	193	189	-40
13	241	251	-250	-16
14	97	98	-96	-16
15	65	76	-19	-74
16	76	70	62	-32
17	106	106	-88	-59
18	115	107	-107	2
19	50	40	-33	23
20	37	39	38	-5
H= 4,L= 3				
0	12	26	0	-26
1	123	103	-99	-30
2	259	237	-6	-237
3	193	183	-48	-177
4	190	180	-166	-70
5	136	157	152	-40
6	203	209	202	53
7	170	189	-125	-142
8	325	317	-317	0

Table 3 (*cont.*)

9	84	73	66	-31
10	186	188	95	161
11	208	211	-81	-194
12	38	36	34	-11
13	121	122	102	-68
14	64	65	-21	61
15	94	95	3	-95
16	42	40	37	-15
17	58	52	-1	-52
18	53	48	-47	12
19	82	85	1	-85
H= 4,L= 4				
0	144	150	-150	0
1	284	278	-79	266
2	288	286	-197	-207
3	419	427	397	158
4	66	61	45	-41
5	129	136	-26	133
6	247	252	-107	-228
7	287	293	147	253
8	256	245	-244	-23
9	69	78	72	30
10	176	182	98	-153
11	79	87	75	43
12	102	116	-101	-56
13	94	89	71	53
14	38	37	37	-3
15	136	131	-121	50
16	133	128	-128	-7
17	29	28	28	-0
18	40	35	2	35
19	48	47	-47	-1
H= 4,L= 5				
0	40	33	-0	-33
1	129	113	-13	-112
2	353	350	-156	-313
3	54	68	67	-11
4	54	60	57	19
5	172	178	-171	48
6	301	301	-284	-100
7	289	293	279	89
8	24	22	3	-22
9	56	52	-11	-51
10	142	153	-152	-14
11	221	237	223	79
12	67	69	-65	20
13	81	87	-61	62
14	113	114	-103	48
15	87	88	32	82
16	116	114	-111	26
17	43	41	19	37
18	22	19	18	5
19	53	67	-60	31
H= 4,L= 6				
0	-23	12	-12	-0
1	155	164	69	149
2	435	452	430	-139
3	206	204	-194	62
4	239	260	241	98
5	47	45	41	19
6	276	279	189	-205
7	71	71	-48	51
8	207	209	184	98
9	39	24	-24	4
10	69	81	-2	-81
11	28	22	-18	-12
12	207	230	209	97
13	65	58	-57	-9
14	82	86	-51	68
15	72	68	65	19
16	128	115	112	26
17	23	21	-21	0
18	50	58	-40	43
H= 4,L= 7				
0	68	73	0	-73
1	44	53	-45	-27
2	266	234	117	203
3	77	86	-55	-66
4	158	170	-164	-43
5	241	249	135	209
6	174	174	165	55
7	165	174	-40	170
8	175	178	-164	-70
9	69	72	71	15
10	159	175	172	-30
11	67	71	32	63
12	20	18	-18	0
13	89	89	51	73
14	107	101	95	-35
15	87	81	51	62
16	72	71	69	-13
17	60	63	-46	43
H= 4,L= 8				
0	55	60	60	0
1	206	206	-136	-154
2	147	146	-144	-25
3	104	106	48	-95
4	177	171	78	-152
5	114	119	-119	0
6	118	122	-118	-32
7	209	233	-120	-200
8	171	183	-75	-167
9	74	84	43	-72
10	39	46	10	-45
11	120	115	-71	-91
12	159	144	-90	-113
13	134	125	117	-45
14	76	71	57	-43
15	68	68	-35	-58
16	59	66	-63	-19
H= 4,L= 9				
0	147	156	-0	156
1	18	18	2	17
2	42	38	-35	-15
3	108	96	64	-71
4	135	133	42	126
5	53	59	-52	-29
6	77	89	-88	-9
7	96	106	41	-97
8	116	126	117	-47
9	133	132	-35	-127
10	129	123	-119	-31
11	111	106	9	-105
12	89	80	35	-71
13	138	122	25	-119
14	20	21	-11	18
15	81	90	-44	-89
H= 4,L=10				
0	270	273	-273	0
1	82	80	29	74
2	59	55	18	52
3	63	59	-41	41
4	135	132	-122	50
5	141	138	-65	122
6	45	51	-20	47
7	36	37	-13	-34
8	149	148	-146	24
9	141	139	-73	119
10	132	122	-118	30
11	66	58	43	39
12	38	32	22	24
13	40	35	-35	-1
14	59	73	-73	-5
H= 4,L=11				
0	123	124	0	124
1	107	107	83	-68
2	94	97	97	7
3	59	60	-6	59
4	97	97	-81	53
5	122	115	114	-13
6	56	49	49	6
7	101	98	-70	69
8	99	92	-91	14
9	94	82	34	74
10	59	57	50	27
11	51	47	-34	-32
12	65	73	-60	-41
H= 4,L=12				
0	224	216	216	-0
1	42	41	-39	-14
2	44	38	-1	-38
3	52	51	48	18
4	164	145	145	-3
5	36	29	-27	-11
6	75	67	66	9
7	61	54	-20	50
8	52	49	49	0
9	28	27	27	5
10	49	70	61	-34
H= 4,L=13				
0	54	49	-0	-49
1	23	24	-1	24
2	8	9	-7	-6
3	12	19	-6	-18
4	68	62	60	15
5	38	34	-25	23
6	17	8	-4	6
7	40	43	11	42
H= 4,L=14				
0	27	33	-33	-0
1	49	55	24	-50
H= 5,L= 0				
1	17	39	0	-39
2	83	20	0	-20
3	242	241	0	-241
4	222	213	-0	-213
5	421	414	0	414
6	245	236	0	236
7	251	251	-0	-251
8	147	133	0	-133
9	137	131	0	131
10	206	205	-0	205
11	68	63	0	-63
12	61	59	0	-59
13	130	130	0	130
14	116	123	-0	123
15	46	46	-0	46
16	104	107	0	107
17	150	143	-0	-143
18	60	56	0	56
19	64	63	-0	63
H= 5,L= 1				
0	93	89	0	89
1	236	234	189	-138
2	343	343	25	-342
3	255	262	260	38
4	56	54	52	12
5	269	277	256	-107
6	177	174	94	-146
7	290	293	114	-270
8	259	261	-87	-245
9	92	94	82	46
10	39	38	29	-24
11	212	219	63	-209
12	281	284	28	-283
13	124	127	78	100
14	135	138	-67	120
15	180	179	-13	-178
16	167	164	-70	-149
17	49	38	-4	37
18	55	54	2	54
19	29	27	-23	-14
H= 5,L= 2				
0	157	175	-175	0
1	220	210	-109	-179
2	140	144	-104	-99
3	184	183	181	-28
4	295	302	21	301
5	188	199	-52	-192
6	221	224	-64	-214
7	148	151	81	127
8	269	269	-128	236
9	146	157	111	-111
10	197	200	103	-171
11	156	153	124	90
12	72	77	10	76
13	167	174	160	73
14	35	40	-17	-36
15	40	40	36	-16
16	120	113	29	-109
17	140	136	130	40
18	21	14	-13	-4
19	40	43	36	-24
H= 5,L= 3				
0	105	101	0	101
1	107	114	-110	-28
2	125	137	99	94
3	175	183	-151	-102
4	117	111	109	-19
5	207	217	-214	31
6	93	94	-94	-5
7	175	179	-177	23
8	84	121	58	106
9	198	214	-196	-94
10	89	82	79	-20
11	153	153	-90	124
12	70	68	-2	68
13	143	159	-139	-76
14	114	114	-62	-95
15	79	79	-35	70
16	55	53	-35	40
17	29	33	-31	-11
18	32	28	1	-28
19	37	46	-6	45
H= 5,L= 4				
0	43	12	-12	-0
1	104	92	-85	-36
2	106	114	-7	-114
3	48	55	-39	38
4	149	149	90	-117
5	120	133	-65	116
6	39	30	14	26
7	109	114	-93	-65
8	153	149	76	-128
9	104	101	-87	51
10	192	206	109	-178
11	168	183	-179	-41
12	188	199	-3	-199
13	106	120	-114	35
14	142	131	24	-120
15	115	114	-109	31
16	56	46	0	-46
17	110	107	-89	-60
18	120	128	8	-128
H= 5,L= 5				
0	79	117	0	117
1	150	154	73	-137
2	108	118	85	82
3	59	69	66	-15
4	265	291	-43	287
5	144	156	127	-89
6	239	238	-104	214
7	54	49	-3	-49
8	108	112	-31	108
9	114	123	-27	-120
10	167	169	39	164
11	32	27	-3	-27
12	82	90	-59	68
13	88	80	-13	79
14	172	165	15	165
15	58	56	37	-41
16	53	48	-35	-33
17	64	60	-40	44
18	15	20	20	2
H= 5,L= 6				
0	20	20	-20	0
1	120	126	10	-126
2	67	69	-63	28
3	176	175	148	94
4	113	121	-6	121
5	186	188	180	-56
6	63	65	-65	-7
7	119	114	90	-70
8	167	176	116	132
9	174	177	157	-82
10	79	85	2	85
11	44	53	19	49
12	152	157	68	141
13	105	97	97	1
14	108	105	15	103
15	63	52	-22	-47
16	46	45	26	37
17	42	47	-14	44
H= 5,L= 7				
0	327	345	-0	-345
1	165	162	77	143
2	152	105	89	-55
3	170	167	77	-149
4	289	293	-68	-285
5	165	167	167	-1
6	98	107	56	-91
7	58	60	43	-42
8	40	43	30	-30
9	138	152	144	-47
10	63	77	53	-55
11	81	80	71	36
12	76	81	58	56
13	138	135	111	-76
14	88	79	14	-76
15	62	61	-9	60
16	82	86	74	44
H= 5,L= 8				
0	-24	22	22	0
1	44	48	-30	37
2	13	18	-18	-2
3	83	89	87	16
4	227	226	18	-226
5	161	177	9	176
6	110	120	77	92
7	173	186	108	-152
8	177	200	-46	-194
9	89	87	70	42
10	68	72	55	46
11	121	112	103	-44
12	22	98	-23	-95
13	53	48	47	-5
14	61	60	58	12
15	50	52	51	11
H= 5,L= 9				
0	128	132	0	132
1	196	201	-167	-113
2	126	134	14	-133
3	222	224	-167	149
4	94	105	-37	98
5	112	117	-35	-112
6	139	154	-139	-66
7	120	126	-125	-21
8	63	64	-60	-21
9	76	73	-24	69
10	42	37	-35	-12
11	113	93	-49	-79
12	90	78	-6	-77
13	56	55	-0	55
14	60	65	-29	59
H= 5,L=10				
0	49	56	56	-0
1	37	44	-16	41
2	74	78	-30	-71
3	125	135	22	133
4	45	46	-18	42
5	85	89	-48	-74
6	113	112	-15	-111
7	159	150	-61	137
8	47	45	14	43
9	92	87	-5	-87
10	113	105	-18	-103
11	26	28	-16	23
12	31	26	23	13
13	26	26	21	-10
H= 5,L=11				
0	27	7	0	7
1	82	76	36	66
2	262	252	5	252
3	68	64	30	-57
4	48	42	-2	41
5	32	29	-19	22
6	124	112	-4	112
7	52	47	41	22
8	85	76	-19	73
9	28	32	-2	-32
10	57	59	55	-22
11	33	42	42	3
H= 5,L=12				
0	51	45	45	0
1	11	2	0	2
2	35	31	9	30
3	88	70	-66	-21
4	18	20	17	-9
5	59	52	-13	50
6	130	113	-3	113
7	51	50	-32	-39
8	16	15	15	1
9	34	42	-39	-15
H= 5,L=13				
0	111	36	-0	-36
1	33	30	9	-28
2	12	11	-0	-5
3	61	60	41	44
4	-15	0	0	1
5	53	54	54	8
H= 6,L= 0				
0	623	603	603	-0
1	334	299	-299	0
2	231	222	222	-0
3	367	345	345	0
4	579	553	553	-0
5	180	166	-166	0
6	172	156	156	-0
7	49	52	52	0
8	73	74	74	-0
9	157	153	153	0
10	229	208	208	-0
11	101	103	-103	-0
12	74	75	-75	-0
13	133	133	133	-0
14	60	58	58	-0
15	145	144	-146	0
16	35	36	-36	0
17	158	139	139	-0
18	25	22	22	0
H= 6,L= 1				
0	45	50	0	-50
1	87	83	-70	44
2	110	110	18	-108
3	171	150	142	72
4	222	219	216	31
5	225	217	-144	162
6	181	177	-174	-33
7	205	221	218	37
8	258	261	260	-25
9	185	183	-159	91
10	29	29	-28	9
11	92	96	60	75
12	122	124	124	0
13	35	42	-36	22
14	61	57	33	47
15	46	35	-7	-35
16	82	73	55	-48
17	37	26	23	11
18	62	67	64	17
H= 6,L= 2				
0	230	251	-251	0
1	352	369	216	-299
2	122	118	86	-80
3	116	118	6	-118
4	263	244	-241	-40
5	293	286	80	-274
6	116	114	-104	-52
7	56	63	-23	-59
8	83	83	-79	24
9	98	96	15	-94
10	123	127	-95	-84
11	172	177	173	-35
12	55	57	-26	51
13	64	62	-26	-56
14	103	105	-104	-19
15	61	59	46	-35
16	85	75	54	51
17	53	54	-50	10
18	21	22	12	-18
H= 6,L= 3				
0	8	18	0	-18
1	31	37	31	-19
2	245	259	185	181
3	136	145	-142	-30
4	97	141	-45	133
5	137	142	67	-126
6	248	243	228	85
7	103	107	-103	-29
8	61	64	40	-49
9	283	291	175	-232
10	196	210	200	-65
11	47	48	-4	-48
12	83	90	-59	67
13	176	177	-0	-177
14	66	62	55	-29
15	113	111	38	-104
16	37	33	32	3
17	123	125	-34	-120
18	60	75	-35	-66
H= 6,L= 4				
0	176	178	178	-0
1	130	134	-129	33
2	162	179	-144	106
3	137	134	-22	132
4	33	36	34	-11
5	167	171	-116	126
6	163	161	-102	125
7	102	110	-88	67
8	69	72	47	-55
9	137	138	9	137
10	157	167	-96	137
11	190	209	-139	156
12	119	116	-115	16
13	75	78	46	63
14	55	53	5	53
15	91	87	-70	52
16	93	90	-90	7
17	59	59	46	37
H= 6,L= 5				
0	26	16	-0	-16
1	157	152	8	152
2	107	100	12	99
3	142	138	137	-10
4	27	27	-10	24
5	75	75	10	75
6	59	60	-45	40
7	63	57	43	37
8	45	45	-1	-45
9	165	176	-114	134
10	142	143	-143	8
11	64	69	0	69
12	49	48	-41	24
13	69	68	27	64
14	109	103	-103	-4
15	76	69	-28	63
16	75	80	-78	-17
17	47	54	19	50
H= 6,L= 6				
0	45	47	47	-0
1	189	178	165	67
2	267	255	253	29
3	60	65	45	47
4	16	15	5	-14
5	135	144	9	144
6	212	209	203	50
7	37	21	-16	14
8	114	124	119	-35
9	81	92	-23	89
10	67	72	61	38
11	181	177	168	54
12	163	149	133	-68
13	63	64	-56	30
14	23	23	10	-21
15	39	38	34	17
16	49	59	54	-25
H= 6,L= 7				
0	60	59	0	-59
1	55	51	16	-48
2	112	82	80	-16
3	159	161	-136	86
4	58	38	-10	37
5	122	126	14	-125
6	167	184	184	0
7	148	156	-150	-41
8	17	22	4	21
9	94	94	75	56
10	160	156	145	-57
11	81	79	-74	-28
12	66	63	57	26
13	47	38	-17	33
14	41	35	35	-4
15	26	26	-5	25
H= 6,L= 8				
0	42	33	33	-0
1	149	160	-80	-138
2	151	161	-159	25
3	181	170	114	-138
4	35	33	-32	3
5	167	189	-21	-188
6	50	49	-36	33
7	13	10	10	-0
8	35	32	-29	-11
9	144	134	68	-114
10	30	31	30	6
11	63	57	-53	-20
12	51	49	-42	24
13	43	43	30	-30
14	48	58	58	-4
H= 6,L= 9				
0	49	55	-0	-55
1	74	69	-69	-0
2	57	50	-33	-37
3	78	80	65	-46
4	107	109	109	-2
5	157	156	-148	-48
6	59	55	-54	-9
7	150	145	135	-53
8	68	71	71	-2
9	120	111	-104	-40
10	27	24	-2	24
11	91	79	63	-46
12	74	70	50	48
13	32	37	-29	-22
H= 6,L=10				
0	180	178	-178	0
1	173	176	134	111
2	61	56	-39	-41
3	89	89	-61	63
4	150	147	-147	-5
5	135	123	56	109
6	93	83	-76	-34
7	72	65	-7	65
8	34	36	25	26
9	50	44	-13	42
10	82	79	-75	-23
11	73	83	83	-1
H= 6,L=11				
0	113	102	-0	-102
1	26	23	12	-20
2	44	43	-10	42
3	22	24	-21	-11
4	75	73	-73	-3
5	47	42	35	-22
6	49	45	35	28
7	26	25	-14	-21
8	113	118	-104	-55
9	54	69	54	-43
H= 6,L=12				
0	22	20	20	-0
1	26	30	-27	12
2	54	52	17	49
3	25	26	25	-7
4	46	47	47	-2
5	42	40	-24	31
6	35	36	31	19
H= 7,L= 0				
1	53	40	-0	40
2	195	194	0	194
3	20	0	-0	0
4	120	102	0	102
5	72	66	0	66
6	196	177	0	177
7	183	176	-0	-176
8	59	57	0	57
9	59	51	0	51
10	157	158	0	158
11	100	97	-0	-97
12	154	151	0	151
13	24	21	-0	-21
14	31	17	0	17
15	12	0	0	0
16	83	78	0	78
17	9	10	-0	10
H= 7,L= 1				
0	190	186	-0	-186
1	264	268	173	-204
2	309	304	43	-300
3	262	247	104	224
4	201	217	-79	-201
5	98	100	-9	-99
6	196	198	-94	-174
7	161	157	113	108
8	123	124	4	-124
9	50	51	47	20
10	29	25	20	16
11	64	60	16	-58
12	53	54	5	-54
13	74	65	-37	53
14	34	30	30	1
15	84	70	27	-64
16	80	72	67	-26
17	38	44	40	18
H= 7,L= 2				
0	19	6	6	0
1	171	177	143	104
2	45	55	47	-27
3	284	287	-53	282
4	105	109	-109	10
5	192	193	193	-5
6	99	92	-13	-91
7	190	192	112	156
8	17	9	-4	9
9	127	137	85	-107
10	121	133	-129	-31
11	96	104	84	61
12	71	67	-23	-63
13	83	80	39	-70
14	65	60	-26	-54
15	121	109	96	-52
16	62	64	-0	-64
17	27	32	32	6
H= 7,L= 3				
0	165	177	-0	-177
1	237	252	-145	206
2	92	97	33	91
3	224	228	-212	-84
4	106	110	-105	-35
5	94	106	-80	69
6	99	101	70	72
7	159	156	-156	9
8	118	121	120	13
9	58	55	-54	-11
10	57	54	19	-52
11	104	105	-105	9
12	74	79	-39	69
13	127	119	-63	-101
14	68	59	3	-59
15	50	47	-38	27
16	36	36	-5	35
H= 7,L= 4				
0	55	78	78	-0
1	29	21	-19	-8
2	112	114	-34	109
3	160	171	40	-166
4	67	68	-11	-67
5	160	163	-53	154
6	47	41	-17	-37
7	162	184	-37	-181
8	156	171	-33	-168
9	117	125	-65	106
10	131	140	-66	123
11	58	51	-25	-45
12	63	58	-11	-57
13	15	94	-82	45
14	15	11	-7	-8
15	34	73	-65	32
16	62	71	-8	-71
H= 7,L= 5				
0	243	250	0	250
1	143	146	37	-142
2	46	40	7	39
3	210	217	-36	214
4	142	151	95	117
5	20	30	-8	-28
6	66	71	66	25
7	62	58	38	43
8	144	156	61	143
9	186	219	101	194
10	136	136	56	124
11	87	84	49	-68
12	100	94	93	16
13	143	133	13	132
14	88	86	5	86
15	62	61	18	-58
H= 7,L= 6				
0	36	38	38	0
1	43	47	-36	-30
2	88	94	91	-26
3	19	18	-5	17
4	85	88	16	86
5	113	125	-30	-121
6	63	68	61	-30
7	132	145	-29	142
8	159	155	-26	153
9	125	119	36	-113
10	18	20	20	-3
11	52	47	-34	31
12	116	111	-30	106
13	-18	4	3	-2
14	40	45	-26	36
15	12	17	-17	-1
H= 7,L= 7				
0	149	153	-0	-153
1	130	133	118	60
2	45	42	-16	-38
3	126	129	126	-25
4	76	84	41	-73
5	69	64	-11	65
6	61	61	-25	-55
7	167	163	158	39
8	66	63	-12	-62
9	31	23	12	-19
10	117	99	8	-99
11	86	81	37	72
12	9	6	-0	6
13	24	31	-14	-28
14	34	44	-24	-37
H= 7,L= 8				
0	13	0	0	-0
1	56	61	57	21
2	98	96	-72	63
3	86	89	-10	-88
4	11	15	-6	-14
5	136	122	70	100
6	96	85	-85	-2
7	85	82	36	-74
8	64	57	0	-57
9	89	83	31	76
10	36	29	-23	17
11	45	71	58	-41
12	17	11	-11	0
13	49	64	33	55
H= 7,L= 9				
0	13	9	0	9
1	132	133	-96	-92
2	73	72	-10	-71
3	147	146	-131	65
4	41	41	41	-5
5	149	137	-136	10
6	36	27	-12	-24
7	76	71	-70	11
8	40	39	25	-30
9	51	46	-44	12
10	38	39	-14	36
11	21	33	-29	-16
H= 7,L=10				
0	25	17	-17	-0
1	24	31	-4	-30
2	67	63	63	-8
3	57	49	-31	38
4	22	18	4	17
5	10	9	-7	-6
6	94	87	16	-86
7	35	34	-8	32
8	-16	11	-10	4
9	25	35	-31	-17
H= 7,L=11				
0	-17	11	0	11
1	48	51	16	48
2	86	75	33	67
3	21	21	-4	-21
4	30	31	-14	27
5	66	61	52	32
6	52	54	18	51
7	7	4	-3	-2
H= 7,L=12				
0	-14	12	12	0
1	33	32	-7	-31
H= 8,L= 0				
0	131	121	121	-0
1	36	21	-21	0
2	36	32	32	-0
3	60	55	-55	-0
4	22	9	-9	-0
5	13	7	7	0
6	139	130	130	-0
7	59	68	-68	0
8	165	163	163	-0
9	34	36	36	0
10	96	96	96	-0
11	56	53	-53	-0
12	78	73	73	-0
13	150	132	132	0
14	122	111	111	0
15	12	4	4	0
16	25	35	35	-0
H= 8,L= 1				
0	33	41	0	41
1	53	60	-58	-15
2	64	64	-38	53
3	87	77	-14	76
4	62	50	49	-9
5	162	165	-141	-86
6	27	18	18	0
7	36	22	10	19
8	63	63	41	-48
9	95	99	-77	60
10	52	54	42	-34
11	74	65	41	50
12	108	102	93	-41
13	89	78	-6	78
14	94	88	80	-36
15	66	58	-21	54
16	35	37	36	11
H= 8,L= 2				
0	40	46	-46	0
1	67	73	31	-66
2	56	53	-24	47
3	176	178	-118	-134
4	125	130	-118	54
5	81	83	-5	-83
6	37	32	-28	16
7	120	124	32	-120
8	28	27	27	-2
9	133	132	-73	-109
10	82	74	-51	53
11	106	106	45	-96
12	60	55	11	-53
13	103	94	-83	-44
14	64	63	-63	3
15	99	109	105	-29
H= 8,L= 3				
0	44	50	0	50
1	119	124	116	45
2	71	74	-70	22
3	15	7	7	-0
4	59	55	-53	-16
5	197	210	206	-40
6	24	23	-1	-23
7	158	167	-126	-109
8	131	140	-107	91
9	42	38	38	2
10	26	18	-18	-2
11	145	137	-110	-75
12	10	17	-16	4
13	50	45	-20	-41
14	18	12	1	-12
15	84	92	-3	-92
H= 8,L= 4				
0	72	74	-74	0
1	222	250	-163	188
2	168	176	-176	12
3	169	186	160	95
4	94	101	-96	31
5	127	134	-74	111
6	149	155	-138	70
7	112	127	-56	114
8	137	134	-106	87
9	68	68	50	46
10	11	13	-1	13
11	129	120	-120	9
12	119	111	-98	51
13	90	84	82	17
14	24	22	15	-16
15	90	115	-115	10
H= 8,L= 5				
0	52	46	-0	46
1	9	12	-0	-12
2	64	76	-75	11
3	99	102	90	49
4	49	53	44	30
5	177	196	-195	23
6	173	166	-164	25
7	175	164	162	23
8	31	33	14	30
9	78	76	-76	-1
10	138	135	-134	10
11	95	81	56	58
12	46	36	-13	-34
13	35	37	-37	-0
14	76	89	-88	13
H= 8,L= 6				
0	112	119	119	-0
1	94	108	104	-30
2	140	158	157	12
3	146	153	-144	-53
4	88	85	85	5
5	96	100	99	-15
6	58	67	67	-0
7	63	57	54	-18
8	114	103	103	2
9	39	25	-24	6
10	70	63	56	-27
11	33	34	32	-9
12	32	33	16	28
13	55	61	-58	20
H= 8,L= 7				
0	56	57	0	-57
1	25	17	-16	5
2	55	63	19	-60
3	54	59	-54	23
4	64	70	5	-70
5	90	84	68	49
6	73	75	60	-45
7	91	83	-81	20
8	42	39	35	-17
9	30	28	19	20
10	49	50	49	8
11	95	103	-54	87
12	29	34	18	29
H= 8,L= 8				
0	15	8	8	-0
1	116	113	-69	-90
2	59	62	-61	13
3	83	80	57	-56
4	28	23	-10	-20
5	80	82	-25	-79
6	44	43	-41	12
7	106	94	17	-92
8	20	18	-6	-17
9	49	49	1	-49
10	33	37	28	24
11	31	38	-22	-31
H= 8,L= 9				
0	16	26	0	26
1	12	26	7	25
2	22	22	-5	21
3	27	21	17	-13
4	22	20	-18	9
5	48	41	-32	-28
6	54	49	-38	30
7	47	52	9	-52
8	8	18	16	7
9	42	45	-22	-39
H= 8,L=10				
0	8	5	-5	[illegible]
1	45	41	34	22
2	21	28	-11	25
3	66	63	-30	56
4	61	53	-49	21
5	32	33	32	3
6	22	24	-24	-3
H= 8,L=11				
0	23	27	0	-27
1	50	53	26	46
H= 9,L= 0				
1	32	25	-0	25
2	15	6	0	6
3	186	168	-0	-168
4	58	54	0	-54
5	49	54	-0	54
6	58	48	0	48
7	82	73	0	-73
8	19	13	0	-13
9	121	115	0	115
10	146	136	0	136
11	64	59	-0	-59
12	9	5	0	5
13	-16	7	-0	7
14	109	124	0	124
H= 9,L= 1				
0	26	3	-0	-3
1	79	87	6	-86
2	109	117	-61	-100
3	13	18	-3	15
4	50	48	48	-3
5	78	73	68	-26
6	129	118	64	-99
7	48	41	22	-35
8	49	44	6	-44
9	75	75	70	26
10	129	117	-21	-115
11	100	84	48	-71
12	80	75	1	-75
13	67	69	46	51
14	30	33	13	-31
H= 9,L= 2				
0	87	95	-95	-0
1	67	73	-67	-28
2	57	61	-60	-9
3	80	81	81	-4
4	30	26	2	-26
5	134	131	-49	-122
6	116	111	-43	-102
7	120	111	27	108
8	57	53	-11	-51
9	95	81	45	-67
10	105	92	42	-82
11	80	69	57	39
12	18	13	3	12
13	74	73	72	-9
H= 9,L= 3				
0	44	43	-0	-43
1	171	182	-147	106
2	39	46	-46	3
3	176	189	-128	-139
4	114	105	-25	-103
5	203	198	-194	40
6	61	64	-37	-52
7	74	65	-39	-51
8	34	34	0	-34
9	131	119	-76	-92
10	82	74	-71	-22
11	95	89	-23	86
12	29	29	-2	-29
13	80	85	-35	-77
H= 9,L= 4				
0	46	42	42	-0
1	108	116	37	109
2	19	14	13	-7
3	126	131	-122	-48
4	75	74	59	-44
5	93	95	-10	95
6	70	62	4	62
7	113	110	-69	-85
8	26	23	12	-19
9	131	118	-46	108
10	67	55	54	-7
11	85	86	-58	-63
12	34	30	-19	-23
13	34	40	-30	-26
H= 9,L= 5				
0	146	156	0	156
1	151	156	97	-122
2	86	93	-24	89
3	136	139	103	89
4	182	171	-29	169
5	65	64	64	9
6	88	87	-7	87
7	79	70	69	10
8	40	44	33	28
9	28	30	11	28
10	-17	44	-38	22
11	34	37	-3	-32
12	16	11	-9	6
H= 9,L= 6				
0	-22	3	3	-0
1	74	70	9	-70
2	49	50	21	45
3	56	56	-36	43
4	69	63	1	63
5	140	131	-35	-126
6	8	11	9	7
7	50	47	-12	45
8	53	49	-13	47
9	109	110	-91	-60
10	63	66	-16	63
11	27	41	3	41
H= 9,L= 7				
0	58	54	0	-54
1	107	106	41	98
2	20	25	19	-16
3	58	62	10	-61
4	101	103	-37	-96
5	67	57	54	20
6	79	73	58	-43
7	18	22	-9	-20
8	42	43	-24	-36
9	48	53	45	-28
10	23	29	18	-22
H= 9,L= 8				
0	42	36	36	-0
1	24	21	-4	20
2	-18	9	-9	-2
3	20	22	-4	-21
4	18	15	1	-15
5	11	20	13	14
6	12	12	10	7
7	19	25	12	-22
8	20	22	-7	-21
H= 9,L= 9				
0	18	13	0	13
1	40	36	-26	-25
2	31	32	-19	-26
3	37	33	-27	19
4	-15	5	2	-4
5	49	48	-31	-37
H=10,L= 0				
0	141	123	123	-0
1	173	156	-156	0
2	151	136	136	-0
3	157	136	136	-0
4	25	161	161	-0
5	35	29	-29	0
6	54	50	50	-0
7	110	100	100	-0
8	66	50	50	0
9	69	56	56	0
10	84	77	77	-0
11	32	30	-30	-0
H=10,L= 1				
0	21	26	0	-26
1	33	36	-33	14
2	71	64	36	-53
3	88	86	77	-32
4	76	[illegible]	37	[illegible]
5	133	[illegible]	-99	[illegible]
6	74	69	61	-31
7	128	117	114	24
8	123	108	100	41
9	105	91	-91	-0
10	38	38	35	16
11	48	47	32	34
H=10,L= 2				
0	77	84	-84	0
1	155	164	134	-95
2	75	76	-63	-41
3	140	136	-110	-75
4	31	24	-1	-25
5	104	99	83	-53
6	52	47	-37	-34
7	86	74	-24	-70
8	63	55	-54	-8
9	55	51	-48	-17
10	63	58	-8	-58
11	23	23	8	-21
H=10,L= 3				
0	-22	13	0	13
1	70	71	-32	-63
2	55	49	36	33
3	102	103	-98	-31
4	35	30	-29	6
5	50	46	12	-45
6	48	44	-29	33
7	83	76	-64	-41
8	19	16	-9	13
9	97	91	76	-50
10	26	28	-17	23
11	59	67	-8	-66
H=10,L= 4				
0	54	52	-52	0
1	102	101	-83	57
2	71	72	-71	-7
3	123	112	9	111
4	62	60	-56	-21
5	55	49	1	49
6	49	37	-19	-31
7	67	68	53	42
8	45	43	-27	-34
9	39	37	10	36
10	11	13	-13	1
H=10,L= 5				
0	12	3	-0	-3
1	21	25	-12	-22
2	63	58	-16	-56
3	82	75	75	1
4	66	64	-43	-47
5	55	47	10	-46
6	56	50	-9	-49
7	71	73	72	-10
8	26	33	-33	0
9	26	32	-32	-1
H=10,L= 6				
0	34	36	36	-0
1	56	58	49	31
2	70	70	65	-26
3	64	64	-36	53
4	46	50	50	2
5	29	37	16	-33
6	80	84	76	-36
7	26	31	-6	30
8	31	34	26	22
H=10,L= 7				
0	24	28	-0	28
1	45	45	3	44
2	44	47	-4	47
3	60	56	-55	-10
4	15	15	1	-15
5	46	57	41	39
6	14	17	4	16
H=10,L= 8				
0	24	33	[illegible]	-0
1	86	90	-82	-38
2	9	13	4	-12
H=11,L= 0				
1	44	33	0	-33
2	35	19	0	-19
3	65	59	-0	-59
4	50	47	0	47
5	64	53	0	53
6	30	26	0	26
7	114	108	-0	-108
8	42	42	0	42
H=11,L= 1				
0	104	91	-0	-91
1	89	85	38	-76
2	84	76	24	-72
3	111	96	66	68
4	85	79	-5	-79
5	74	72	33	-64
6	64	63	-1	-63
7	54	59	35	-47
8	53	61	37	-48
H=11,L= 2				
0	14	19	19	-0
1	22	27	21	-17
2	21	25	-5	-25
3	58	51	-8	51
4	33	29	-28	-6
5	93	92	56	-73
6	31	29	9	26
7	65	70	33	61
8	24	18	-11	13
H=11,L= 3				
0	-17	2	-0	2
1	70	73	-60	41
2	-17	15	7	-12
3	14	21	-20	-8
4	38	34	20	27
5	16	19	-12	15
6	30	34	31	13
7	68	63	-62	-5
H=11,L= 4				
0	-16	[illegible]	[illegible]	[illegible]
1	25	[illegible]	[illegible]	[illegible]
2	21	[illegible]	[illegible]	[illegible]
3	36	[illegible]	[illegible]	[illegible]
4	13	[illegible]	[illegible]	[illegible]
5	44	[illegible]	[illegible]	[illegible]
6	38	[illegible]	[illegible]	[illegible]
H=11,L= 5				
0	47	[illegible]	[illegible]	[illegible]
1	-15	[illegible]	[illegible]	[illegible]
2	40	[illegible]	[illegible]	[illegible]
3	16	[illegible]	[illegible]	[illegible]
4	15	[illegible]	[illegible]	[illegible]

Table 4. *Intramolecular distances and angles*

Atoms	Distance	Atoms	Angle
Al(1)-N(1)	2·192 Å	N(1)-Al(1)-N(3)	178·0°
Al(1)-N(3)	2·238	N(2)-Al(2)-N(4)	176·5
Al(2)-N(2)	2·192		
Al(2)-N(4)	2·200	Al(1)-N(1)-C(1)	108·3
		Al(1)-N(1)-C(2)	109·3
N(1)-C(1)	1·477	Al(1)-N(3)-C(7)	107·2
N(1)-C(2)	1·477	Al(1)-N(3)-C(8)	109·1
N(2)-C(3)	1·472	Al(2)-N(2)-C(3)	107·8
N(2)-C(4)	1·479	Al(2)-N(2)-C(4)	107·6
N(3)-C(7)	1·463	Al(2)-N(4)-C(9)	111·1
N(3)-C(8)	1·469	Al(2)-N(4)-C(10)	106·6
N(4)-C(9)	1·482		
N(4)-C(10)	1·471	Al(1)-N(1)-C(5)	114·5
		Al(1)-N(3)-C(11)	112·9
N(1)-C(5)	1·505	Al(2)-N(2)-C(6)	107·5
N(2)-C(6)	1·486	Al(2)-N(4)-C(12)	113·5
N(3)-C(11)	1·488		
N(4)-C(12)	1·500	C(5)-N(1)-C(1)	105·5
		C(5)-N(1)-C(2)	110·4
C(5)-C(6)	1·527	C(6)-N(2)-C(3)	111·5
C(11)-C(12)	1·507	C(6)-N(2)-C(4)	112·0
Probable errors		N(1)-C(5)-C(6)	113·7
Al-N	±0·004	N(2)-C(6)-C(5)	114·1
N-C	±0·007	N(3)-C(11)-C(12)	112·5
C-C	±0·008	N(4)-C(12)-C(11)	113·8

The average N-CH$_3$ distance is 1·474 ± 0·005 Å and the average N-CH$_2$- is 1·495 ± 0·008 Å. These distances are in agreement with the generally accepted value of 1·479 Å (*International Tables for X-ray Crystallography*, 1962). Following the suggestion of Cruickshank & Robertson (1953), the difference of 0·021 Å between the two types of N-C bonds is on the borderline ($t_0 = 2·6$) of being significant. The lengthening of the N-CH$_2$- bond can be explained either by a steric repulsion effect or by an electronegativity difference between -CH$_3$ and -CH$_2$-. A view down the N-C bond in the N-CH$_2$- case is given in Fig. 2(*a*). It is interesting to note that the Al(2) atom is *trans* to C(5), the position of minimum repulsion. Repulsion between C(5) and both C(3) and C(4) could cause a slight elongation of the bond, N-CH$_2$-, compared with a N-CH$_3$ bond. Another possible explanation would be the difference between a methyl group and the -CH$_2$- group. The methyl group is generally considered to be the most electronegative of the alkyl groups.

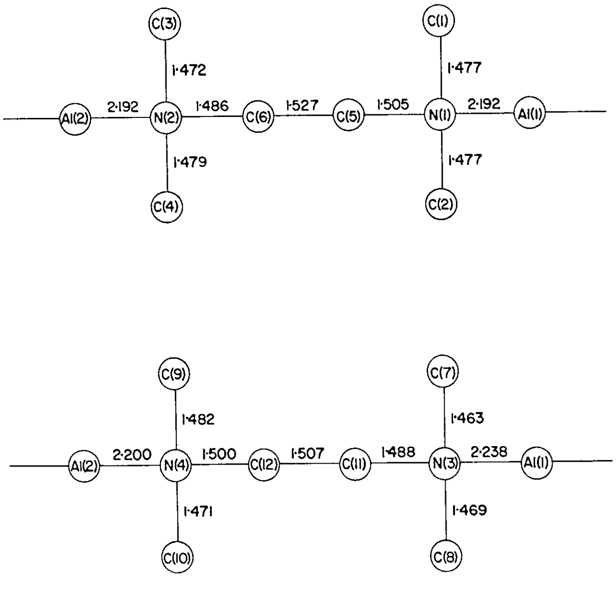

Fig. 1. The atom numbering and bond distances in the two crystallographic tetramethylethylenediamine units.

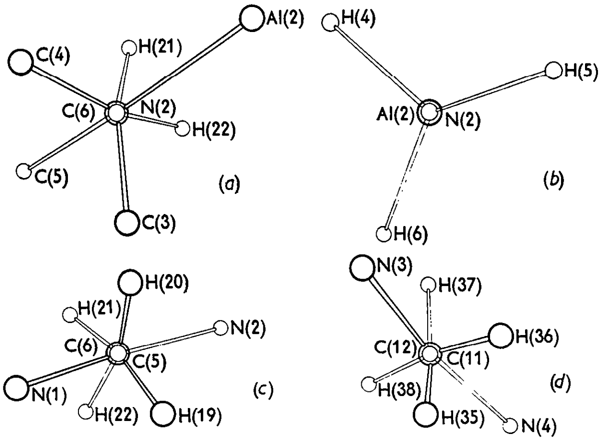

Fig. 2. Views down various bonds in the molecule: (*a*) the N(2)-C(6) bond, (*b*) the N(2)-Al(2) bond, (*c*) the C(5)-C(6) bond and (*d*) the C(11)-C(12) bond.

The Al-N bonds are the most precisely determined bond distances in the present study, but unfortunately present certain difficulties. Three of the four bonds are in good agreement with the average distance of 2·195 ± 0·004 Å. The fourth bond distance of 2·238 Å is significantly longer. The Al-N distance of 2·18 ± 0·01 Å reported by Heitsch, Nordman & Parry (1963) for H$_3$Al[N(CH$_3$)$_3$]$_2$ is in agreement with the shorter Al-N distance. There appears to be no reason to expect the fourth bond to be longer and it is felt that this value should be regarded with suspicion. It should be noted that while the Al(1)-N(3) distance is the longest of the Al-N bonds, the N(3)-C(7) and N(3)-C(8) bonds are the shortest of the N-CH$_3$ bonds. It is possible that there is a strong interaction in this group of atoms and the block approximation is inadequate in this case. While it would be interesting to repeat the refinement using only the full matrix, it is questionable whether the expenditure of time and effort would be profitable.

The thermal parameters given in Table 2 were converted to mean-square displacements and direction cosines and are tabulated in Table 5. The displacements are not unusual for a covalent type molecule. As expected, the methyl groups have the highest

Table 5. *Root-mean-square displacements calculated from the thermal parameters*

Atom	$(r^2)^{\frac{1}{2}}$*	Direction cosines†		
Al(1)	207	9487	−2829	−1412
	183	1330	−0480	9900
	160	2868	9580	0080
Al(2)	207	−1878	4935	−8492
	194	−9639	0736	2559
	152	−1888	−8666	−4619
N(1)	203	9541	−1835	−2366
	175	1876	−2496	9500
	151	2334	9508	2037
N(2)	198	6169	4215	−6646
	187	7860	−3728	4932
	155	0399	8267	5613
N(3)	243	−8605	4472	−2441
	182	−4629	−4862	7412
	168	−2128	−7508	−6254
N(4)	205	−6360	−0024	−7716
	197	−7153	3771	5884
	156	−2895	−9262	2416
C(1)	264	1013	4336	−8954
	237	7118	−6604	−2393
	160	6951	6131	3755
C(2)	266	−8798	0162	−4751
	215	−3534	6462	6764
	150	−3179	−7630	5628
C(3)	309	−7858	2154	5798
	220	−6120	−4072	−6780
	190	−0900	8876	−4517
C(4)	271	−0248	7969	−6036
	198	−9530	1630	2551
	179	−3020	−5816	−7554
C(5)	231	0497	5792	−8137
	195	9982	−0555	0214
	172	0327	8133	5809
C(6)	239	5786	3249	−7481
	185	7003	−6681	2515
	150	4181	6694	6141
C(7)	375	−7182	6943	−0456
	244	−6950	−7126	0962
	166	−0344	−1008	−9943
C(8)	314	5424	−0379	8393
	239	6008	7158	−3560
	196	5873	−6973	−4110
C(9)	308	3475	1617	9236
	220	3214	9048	−2793
	190	8809	−3940	−2624
C(10)	267	−8614	5067	0343
	225	−5008	−8587	1088
	190	−0846	−0765	−9935
C(11)	279	8589	−5120	0130
	225	2628	4623	8469
	155	4397	7239	−5316
C(12)	231	5779	−5748	−5794
	215	7577	1141	6426
	156	3032	8103	−5014

* Values times 10^3, in Ångström units. † Values times 10^4 (cosines are given with respect to **a**, **b**, **c**).

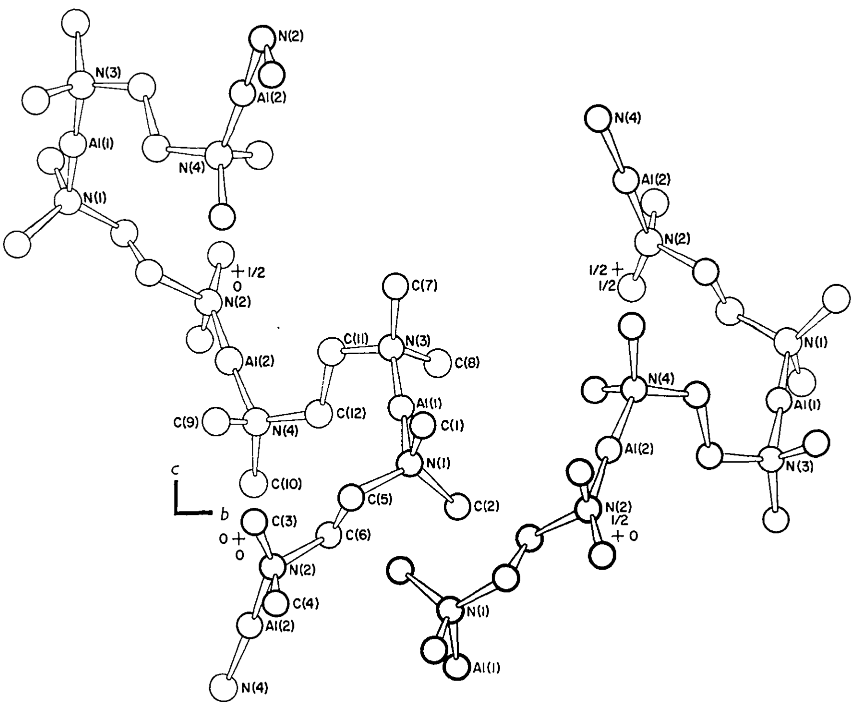

Fig. 3. Projection on the (100) plane illustrating the relationship of two of the infinite chains.

mean square displacement, since they are restrained only by the one N–CH_3 bond.

In the solid state the complex forms infinite chains of alternating aluminum hydride and *N*,*N*,*N′*,*N′*-tetramethylethylenediamine units. Portions of two of these chains projected onto the (100) plane are illustrated in Fig. 3. All the intermolecular distances less than 4·0 Å were computed. As expected for a compound of this type, the van der Waals contacts between the chains are between hydrogen atoms. The hydrogen–hydrogen contacts of less than 2·7 Å are tabulated in Table 6. Except for three short contacts, the distances average 2·61 Å, in reasonable agreement with the 2·4 Å value suggested by Pauling (1960).

Table 6. *Intermolecular distances*

X	Y	Molecule	Distance
H(8) –C(1)	H(29)–C(9)	*A*	2·53 Å
H(8) –C(1)	H(24)–C(7)	*D*	2·67
H(9) –C(1)	H(5) –Al(2)	*C*	2·57
H(10)–C(2)	H(1) –Al(1)	*B*	2·39
H(10)–C(2)	H(37)–C(12)	*B*	2·60
H(12)–C(2)	H(34)–C(10)	*B*	2·62
H(16)–C(4)	H(26)–C(8)	*B*	2·69
H(19)–C(5)	H(5) –Al(2)	*C*	2·38
H(23)–C(7)	H(28)–C(8)	*D*	2·62
H(25)–C(7)	H(28)–C(8)	*D*	2·27
H(29)–C(9)	H(4) –Al(2)	*E*	2·69
H(30)–C(9)	H(6) –Al(2)	*E*	2·58
H(32)–C(10)	H(5) –Al(2)	*E*	2·56
H(33)–C(10)	H(5) –Al(2)	*E*	2·57
H(35)–C(11)	H(6) –Al(2)	*E*	2·58
H(38)–C(12)	H(5) –Al(2)	*E*	2·48

The distances quoted are from X in the molecule specified by the parameters in Table 1 to Y in the molecule specified by the letters *A*–*E*. Molecules *A*–*E* are located as follows:

A	$-x,\ \frac{1}{2}+y,\ \frac{1}{2}-z$	*D*	$\frac{1}{2}+x,\ \frac{1}{2}-y,\ 1-z$
B	$\frac{1}{2}+x,\ \frac{1}{2}-y,\ -z$	*E*	$\frac{1}{2}-x-1,\ -y,\ \frac{1}{2}+z$
C	$\frac{1}{2}-x,\ -y,\ \frac{1}{2}+z$		

The conformation around the aluminum atoms is that of a trigonal bipyramid. Two nitrogen atoms from two different diamine molecules occupy the axial positions with N–Al–N angles of 178·0 and 176·5°. The hydrogen atoms around Al(2) were easily located from the difference Fourier synthesis and are located in the three equatorial positions. A view down the Al(2)–N(2) bond is given in Fig. 2(*b*), illustrating the approximate threefold symmetry of the hydrogen atoms. While the hydrogen atoms around Al(1) were not as well resolved in the difference Fourier synthesis, the positive areas were located around Al(1) with threefold symmetry.

Joining the aluminum hydride groups is the bifunctional diamine chain in the *trans* configuration. Views down the two C–C bonds are given in Fig. 2(*c*) and (*d*) and illustrate the *trans* configuration. This is a departure from the usual *cis* or *gauche* forms of the diamine found when it acts as a bifunctional group.

At least in the solid state the hydrogen-bridged dimer proposed by Davidson & Wartik (1960) is incorrect. Both in this structure and in the $H_3Al[N(CH_3)_3]_2$ structure, aluminum has fivefold coordination with no hydrogen bridges. In either case a hydrogen bridge could easily provide octahedral coordination for the aluminum atom. It appears that hydrogen-bridges in aluminum compounds may not be as common as expected. If one assumes an Al–H (bridge) distance of 1·7 Å and an Al–H–Al angle of 90°, the Al–Al distance would be 2·4 Å. This Al–Al distance is just twice the single-bond radius for aluminum and might be too short for appreciable stability. This Al–Al distance can be increased slightly by increasing the Al–H–Al angle, but then the hydrogen atoms begin to approach each other with nearly van der Waals contact. It is true that boron in its various hydrides has very close B–B contacts but it is possible that aluminum finds this situation intolerable. It is hoped that further structural work on other aluminum complexes will provide more knowledge in this regard.

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