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β-Mg$_2$SiO$_4$: Single-crystal X-ray diffraction study

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Abstract

The crystal structure of β-Mg$_2$SiO$_4$ has been refined using a single crystal synthesized at 185 kbar and 2000°C, by means of X-ray diffraction data. Magnesium and silicon atoms are completely ordered on octahedral and tetrahedral sites, respectively. Octahedral distortions are smaller in MgO$_6$ octahedra and greater in the larger unoccupied octahedra, $\square$O$_6$. The density increase involved in the $\alpha \rightarrow \beta \rightarrow \gamma$ phase transformations is mainly attributed to the volume decrease of unoccupied octahedra. The distortions from regular octahedra and the octahedral volumes in the β-Mg$_2$SiO$_4$ structure are much smaller than those of α-Mg$_2$SiO$_4$ and the octahedral distortions and volumes of MO$_6$ and $\square$O$_6$ will be further decreased in association with the $\beta \rightarrow \gamma$ phase transformation to the minimum degree observed in β-Mg$_2$SiO$_4$.

Introduction

The presence of a complex intermediate phase in the high pressure transformation of olivine(α)$\rightarrow$spinel(γ) was first pointed out for compositions close to nearly iron-free (Mg,Fe)$_2$SiO$_4$ by Ringwood and Major (1966). This intermediate phase was confirmed to be a stable phase by Akimoto and Sato (1968) and Akimoto (1970) by analogy to new high-pressure polymorphs of Co$_2$SiO$_4$ and Mn$_2$GeO$_4$ which were subsequently designated as the "β-phase". A number of phase equilibrium studies of Mg$_2$SiO$_4$–Fe$_2$SiO$_4$ were subsequently initiated, because the phase transformations $\alpha \rightarrow \beta \rightarrow \gamma$ of this system are believed to directly involve the structure and constitution of the transition zone in the earth's mantle. For example, phase equilibria in the system MgO–FeO–SiO$_2$ and in pure Mg$_2$SiO$_4$ up to pressures around 200 kbar were reported by Akimoto (1972) and by Suito and Kawai (1979), respectively, and the post-spinel phases of Mg$_2$SiO$_4$ were studied by several investigators such as Kumazawa, Sawamoto, Ohtani and Masaki (1974), Liu (1976), Ito (1977) and others.

The crystal structure of the β-phase was determined by Morimoto, Akimoto, Koto and Tokonami (1969) for a single crystal of Mn$_2$GeO$_4$, and almost simultaneously by Moore and Smith (1970) for a powder specimen of (Mg$_{0.9}$Ni$_{0.1}$)$_2$SiO$_4$ synthesized by Ringwood and Major (1969). Following the determination of the crystal structures of the aforementioned compounds, those of β–Co$_2$SiO$_4$ and Ni$_3$Al$_2$SiO$_8$ III(β-phase) were also studied in detail by Morimoto, Tokonami, Watanabe and Koto (1974), and Ma and Sahl (1975), respectively.

Precise studies on the crystal structures of β- and γ-phases of Mg$_2$SiO$_4$ have not been carried out because of technical difficulties in obtaining single crystals large enough for single-crystal investigations, although its prime importance has been widely recognized in the investigation of mantle substances.

In this work, the crystal structure of pure β-Mg$_2$SiO$_4$ was refined using single crystal X-ray diffraction data. The crystal structure is described in detail in comparison with the α-phase of Mg$_2$SiO$_4$.

Experimental

Single crystals of β-Mg$_2$SiO$_4$ were synthesized from powdered α-Mg$_2$SiO$_4$ crystals at 2000°C and 185 kbar by means of a multi-anvil-type high pressure and high temperature apparatus. The run-time

$\beta \cdot Mg_2SiO_4$: Structural studies on a single crystal

by

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Fobs and Fcalc Tables

CENTROSYMMETRIC

SCATTERING FACTOR TABLE 1

12.000	11.507	10.472	9.502	8.735	8.078	7.446	6.817
6.194	5.595	5.034	4.520	4.059	3.652	3.297	3.013
2.729	2.527	2.317	2.170	2.022	1.917	1.812	1.736
0.	0.	0.	0.	0.	0.	0.	0.

SCATTERING FACTOR TABLE 2

14.000	13.434	12.134	10.769	9.673	8.859	8.231	7.698
7.202	6.719	6.240	5.769	5.312	4.878	4.470	4.110
3.750	3.457	3.164	2.933	2.702	2.524	2.346	2.211
0.	0.	0.	0.	0.	0.	0.	0.

SCATTERING FACTOR TABLE 3

8.000	7.798	7.245	6.472	5.623	4.808	4.089	3.489
3.006	2.629	2.338	2.115	1.946	1.816	1.714	1.641
1.568	1.516	1.463	1.420	1.377	1.338	1.298	1.260
0.	0.	0.	0.	0.	0.	0.	0.

SYMMETRY OPERATION 1

I	R(I,1)	R(I,2)	R(I,3)	T(I)
1	1.00	0.	0.	0.
2	0.	1.00	0.	0.
3	0.	0.	1.00	0.

SYMMETRY OPERATION 2

I	R(I,1)	R(I,2)	R(I,3)	T(I)
1	1.00	0.	0.	0.
2	0.	-1.00	0.	0.
3	0.	0.	-1.00	0.

SYMMETRY OPERATION 3

I	R(I,1)	R(I,2)	R(I,3)	T(I)
1	1.00	0.	0.	0.
2	0.	1.00	0.	0.5000000
3	0.	0.	-1.00	0.

SYMMETRY OPERATION 4

I	R(I,1)	R(I,2)	R(I,3)	T(I)
1	1.00	0.	0.	0.
2	0.	-1.00	0.	0.5000000
3	0.	0.	1.00	0.

RECIPROCAL CELL PARAMETERS
0.175490   0.087430   0.121120   0.   0.   0.

SCALE = 0.863110   TO = 0.

ATOM LABEL	X	Y	Z		TEMPERATURE FACTOR DATA				
M(1)	0.	0.	0.	0.00247	0.00106	0.00166	0.	0.	0.
M(2)	0.	0.2500	0.9792	0.00353	0.00081	0.00128	0.	0.	0.
M(3)	0.2500	0.1276	0.2503	0.00304	0.00094	0.00167	0.	-0.00031	0.
T	0.	0.1198	0.6168	0.00156	0.00040	0.00084	0.	0.	0.
O(1)	0.	0.2500	0.2146	0.00293	0.00068	0.00138	0.	0.	-0.00004
O(2)	0.	0.2500	0.7164	0.00337	0.00093	0.00130	0.	0.	0.
O(3)	0.	0.9900	0.2553	0.00327	0.00013	0.00130	0.	0.	-0.00010
O(4)	0.2615	0.1225	0.9925	0.00265	0.00057	0.00134	-0.00009	0.00015	0.00001

ATOM LABEL		SCAT.	SITE	OCCUP	OCCA
M(1)	1	0	0.250	1.000	0.
M(2)	1	0	0.250	1.000	0.
M(3)	1	0	0.500	1.000	0.
T	2	0	0.500	1.000	0.
O(1)	3	0	0.250	1.000	0.
O(2)	3	0	0.250	1.000	0.
O(3)	3	0	0.500	1.000	0.
O(4)	3	0	1.000	1.000	0.

FORMAT OF INPUT H K L FO AND SIGF IS (4(3I3,F5.1,F5.2))

SUMFO = 8578.62   SUMFC = 8791.27   NUMBER OF REFLECTIONS 675

R FACTOR = 0.07042

R FACTOR(OMITTING ZERO) = 0.05352 (607 REFLECTIONS)

R FACTOR(USED FOR LS) = 0.02797 (438 REFLECTIONS)

FO AND FC VALUES ARE MULTIPLIED BY 20

*=MARKED REFLECTIONS HAVE BEEN ELIMINATED FROM LS PROCEDURE

H	K	L	FO	FC	H	K	L	FO	FC	H	K	L	FO	FC
0	2	0	60	69	0	17	5	0*	15	1	4	1	1287	1282
0	4	0	818	-816	0	0	6	162	-158	1	6	1	100	93
0	6	0	176	-172	0	2	6	18*	-9	1	8	1	13*	25
0	8	0	2565	2650	0	4	6	255	236	1	10	1	117	-133
0	10	0	113	119	0	6	6	0*	-53	1	12	1	652	645
0	12	0	440	-450	0	8	6	119	-114	1	14	1	136	123
0	14	0	212	-229	0	10	6	22*	61	1	16	1	0*	-22
0	16	0	1125	1112	0	12	6	160	145	1	18	1	62*	-118
0	18	0	119*	87	0	14	6	53*	-38	1	1	2	668	-651
0	1	1	8*	-3	0	16	6	24*	-14	1	3	2	543	-545
0	3	1	10*	0	0	1	7	291	274	1	5	2	342	354
0	5	1	337	330	0	3	7	222	-232	1	7	2	523	524
0	7	1	75	39	0	5	7	0*	27	1	9	2	281	-271
0	9	1	0*	-9	0	7	7	176	-179	1	11	2	441	-430
0	11	1	174	172	0	9	7	195	183	1	13	2	134	126
0	13	1	288	290	0	11	7	281	-294	1	15	2	321	328
0	15	1	22*	-33	0	13	7	0*	-93	1	17	2	0*	-85
0	17	1	0*	11	0	15	7	113*	-81	1	0	3	1087	1069
0	0	2	115	111	0	0	8	1491	1504	1	2	3	119	120
0	2	2	25*	47	0	2	8	378	385	1	4	3	267	253
0	4	2	504	-411	0	4	8	735	-746	1	6	3	12*	-1
0	6	2	115	-118	0	6	8	214	224	1	8	3	721	727
0	8	2	100*	86	0	8	8	1137	1130	1	10	3	136	125
0	10	2	172	173	0	10	8	317	326	1	12	3	96	85
0	12	2	17*	12	0	12	8	485	-497	1	14	3	27*	-73
0	14	2	32*	-90	0	14	8	0*	40	1	16	3	346	330
0	16	2	22*	73	0	1	9	127	123	1	1	4	393	380
0	18	2	181	174	0	3	9	146	-141	1	3	4	567	-547
0	1	3	1135	1122	0	5	9	257	257	1	5	4	490	484
0	3	3	749	733	0	7	9	112*	-101	1	7	4	198	-212
0	5	3	788	-777	0	9	9	60*	103	1	9	4	233	238
0	7	3	1035	-1030	0	11	9	20*	20	1	11	4	293	-297
0	9	3	593	577	0	13	9	236	227	1	13	4	239	238
0	11	3	393	330	0	0	10	193	192	1	15	4	0*	-83
0	13	3	386	-473	0	2	10	15*	7	1	17	4	70*	140
0	15	3	571	-552	0	4	10	126	-124	1	0	5	904	889
0	17	3	157	162	0	6	10	48*	-95	1	2	5	101	91
0	0	4	1895	1896	0	8	10	150	180	1	4	5	115	-112
0	2	4	160	157	0	10	10	56*	85	1	6	5	29*	-34
0	4	4	453	447	0	12	10	0*	-101	1	8	5	681	663
0	6	4	239	246	0	1	11	561	577	1	10	5	160	161
0	8	4	1042	1043	0	3	11	345	364	1	12	5	108*	-97
0	10	4	48*	-37	0	5	11	345	-350	1	14	5	46*	-88
0	12	4	244	259	0	7	11	586	-591	1	16	5	334	318
0	14	4	157	171	0	9	11	379	360	1	1	6	364	354
0	16	4	453	443	0	0	12	153	185	1	3	6	412	402
0	1	5	279	-275	0	2	12	326	339	1	5	6	303	-306
0	3	5	676	-669	0	4	12	74*	-92	1	7	6	398	-406
0	5	5	745	743	0	6	12	341	368	1	9	6	186	171
0	7	5	331	330	0	8	12	157*	151	1	11	6	322	319
0	9	5	126	-111	0	1	13	20*	2	1	13	6	74*	-146
0	11	5	355	-338	0	3	13	107*	-86	1	15	6	264	-258
0	13	5	433	434	1	0	1	22*	4	1	0	7	69*	78
0	15	5	208	215	1	2	1	70*	-57	1	2	7	186	188

H	K	L	FO	FC	H	K	L	FO	FC	H	K	L	FO	FC
1	4	7	509	521	2	13	1	193	-183	2	15	7	195	205
1	6	7	210	209	2	15	1	260	-248	2	0	8	93	99
1	8	7	0*	41	2	17	1	334	318	2	2	8	367	361
1	10	7	0*	62	2	0	2	355	-251	2	4	8	521	507
1	12	7	305	305	2	2	2	32*	-49	2	6	8	208	204
1	14	7	141	134	2	4	2	75*	-58	2	8	8	50*	69
1	1	8	488	486	2	6	2	105	104	2	10	8	286	315
1	3	8	196	-199	2	8	2	119	101	2	12	8	319	308
1	5	8	226	239	2	10	2	43*	-70	2	14	8	0*	46
1	7	8	402	-405	2	12	2	0*	-9	2	1	9	376	378
1	9	8	346	351	2	14	2	146	135	2	3	9	53*	85
1	11	8	94*	-94	2	16	2	0*	18	2	5	9	31*	-26
1	13	8	188	192	2	1	3	27*	7	2	7	9	236	-238
1	0	9	334	-340	2	3	3	283	-272	2	9	9	346	331
1	2	9	41*	97	2	5	3	233	223	2	11	9	58*	91
1	4	9	488	487	2	7	3	272	-264	2	13	9	0*	35
1	6	9	132	182	2	9	3	146	-154	2	0	10	229	239
1	8	9	269	-275	2	11	3	103*	-81	2	2	10	0*	-25
1	10	9	31*	-10	2	13	3	112*	98	2	4	10	172	-163
1	12	9	296	312	2	15	3	248	-258	2	6	10	0*	-11
1	1	10	210	-217	2	17	3	169	-169	2	8	10	139	181
1	3	10	279	-280	2	0	4	811	-799	2	10	10	25*	-36
1	5	10	139	179	2	2	4	138	130	2	1	11	51*	76
1	7	10	224	223	2	4	4	2452	2523	2	3	11	108	-102
1	9	10	136*	-149	2	6	4	215	222	2	5	11	148*	110
1	11	10	257	-242	2	8	4	605	-603	2	7	11	174	-170
1	0	11	157	164	2	10	4	18*	-74	2	9	11	22*	-43
1	2	11	205	219	2	12	4	1329	1314	2	0	12	543	-558
1	4	11	0*	43	2	14	4	179	166	2	2	12	317	325
1	6	11	189	177	2	16	4	334	-334	2	4	12	617	617
1	8	11	132	129	2	1	5	300	303	2	6	12	324	352
1	10	11	163*	167	2	3	5	124	-133	2	1	13	0*	78
1	1	12	0*	21	2	5	5	139	133	3	0	1	258	239
1	3	12	264	-269	2	7	5	82*	-43	3	2	1	12*	-31
1	5	12	243	252	2	9	5	355	345	3	4	1	885	864
1	7	12	0*	28	2	11	5	100*	-102	3	6	1	18*	63
1	0	13	226	216	2	13	5	110*	84	3	8	1	131	118
1	2	13	138*	118	2	15	5	0*	97	3	10	1	94*	-100
2	0	0	821	812	2	0	6	36*	-97	3	12	1	509	490
2	2	0	70	42	2	2	6	34*	-58	3	14	1	29*	95
2	4	0	2080	2064	2	4	6	163	149	3	16	1	24*	37
2	6	0	151	-144	2	6	6	88	91	3	1	2	476	-465
2	8	0	531	528	2	8	6	0*	-55	3	3	2	464	-461
2	10	0	132	122	2	10	6	98*	-116	3	5	2	331	317
2	12	0	807	789	2	12	6	126*	136	3	7	2	453	450
2	14	0	205	-218	2	14	6	72*	144	3	9	2	227	-236
2	16	0	260	232	2	16	6	0*	-74	3	11	2	391	-382
2	18	0	0*	63	2	1	7	500	-500	3	13	2	127	110
2	1	1	926	925	2	3	7	914	-911	3	15	2	296	297
2	3	1	823	805	2	5	7	712	709	3	17	2	0*	-79
2	5	1	540	-525	2	7	7	390	386	3	0	3	1066	1036
2	7	1	593	-573	2	9	7	372	-377	3	2	3	112	101
2	9	1	661	652	2	11	7	678	-678	3	4	3	15*	41
2	11	1	538	537	2	13	7	310	312	3	6	3	36*	-19

H	K	L	FO	FC		H	K	L	FO	FC		H	K	L	FO	FC
3	8	3	742	733		3	5	10	134*	144		4	3	5	526	-505
3	10	3	131	129		3	7	10	212	190		4	5	5	566	546
3	12	3	24*	-6		3	9	10	37*	-130		4	7	5	274	261
3	14	3	0*	-83		3	0	11	195	202		4	9	5	101	-89
3	16	3	364	358		3	2	11	214	201		4	11	5	269	-263
3	1	4	310	300		3	4	11	0*	-9		4	13	5	360	353
3	3	4	412	-413		3	6	11	141*	155		4	15	5	174	184
3	5	4	365	375		3	8	11	177	165		4	0	6	139	-147
3	7	4	182	-186		3	1	12	25*	43		4	2	6	18*	1
3	9	4	220	212		3	3	12	231	-221		4	4	6	220	215
3	11	4	246	-250		3	5	12	207	210		4	6	6	44*	-33
3	13	4	182	206		4	0	0	2582	2677		4	8	6	108	-98
3	15	4	56*	-87		4	2	0	31*	39		4	10	6	50*	43
3	0	5	906	907		4	4	0	561	-549		4	12	6	120*	103
3	2	5	96	87		4	6	0	126	-111		4	14	6	0*	-37
3	4	5	233	-238		4	8	0	1848	1851		4	1	7	170	170
3	6	5	88*	-41		4	10	0	112	100		4	3	7	189	-198
3	8	5	693	679		4	12	0	364	-359		4	5	7	91*	36
3	10	5	150	158		4	14	0	170	-190		4	7	7	127	-117
3	12	5	162	-167		4	16	0	959	936		4	9	7	126*	129
3	14	5	0*	-97		4	1	1	15*	-15		4	11	7	238	-248
3	16	5	369	347		4	3	1	13*	-12		4	13	7	29*	-81
3	1	6	346	344		4	5	1	231	223		4	0	8	1149	1152
3	3	6	376	370		4	7	1	32*	-11		4	2	8	298	295
3	5	6	272	-282		4	9	1	0*	1		4	4	8	588	-585
3	7	6	386	-380		4	11	1	141	151		4	6	8	188	177
3	9	6	162	160		4	13	1	217	224		4	8	8	928	913
3	11	6	276	308		4	15	1	25*	-32		4	10	8	274	274
3	13	6	134	-145		4	0	2	34*	47		4	12	8	409	-418
3	15	6	243	-245		4	2	2	15*	35		4	1	9	110*	101
3	0	7	148	143		4	4	2	17*	0		4	3	9	101*	-98
3	2	7	146	164		4	6	2	48*	-70		4	5	9	201	195
3	4	7	376	372		4	8	2	41*	53		4	7	9	24*	-83
3	6	7	188	173		4	10	2	115	130		4	9	9	53*	91
3	8	7	32*	100		4	12	2	0*	-8		4	11	9	25*	27
3	10	7	63*	68		4	14	2	51*	-69		4	0	10	146	164
3	12	7	224	221		4	16	2	0*	57		4	2	10	0*	-4
3	14	7	126*	108		4	1	3	804	798		4	4	10	55*	-115
3	1	8	443	448		4	3	3	528	523		4	6	10	53*	-88
3	3	8	119	-142		4	5	3	545	-540		4	8	10	132	157
3	5	8	177	185		4	7	3	752	-755		4	1	11	476	476
3	7	8	379	-385		4	9	3	453	438		4	3	11	315	306
3	9	8	324	334		4	11	3	308	305		4	5	11	303	-297
3	11	8	51*	-65		4	13	3	334	-327		4	0	12	176	153
3	13	8	188	165		4	15	3	469	-469		5	0	1	91	-120
3	0	9	229	-232		4	0	4	1034	1034		5	2	1	39*	-28
3	2	9	110	86		4	2	4	53*	88		5	4	1	875	872
3	4	9	367	363		4	4	4	398	389		5	6	1	51*	80
3	6	9	169	155		4	6	4	186	187		5	8	1	93*	-109
3	8	9	181	-187		4	8	4	707	699		5	10	1	62*	-107
3	10	9	0*	-1		4	10	4	27*	-73		5	12	1	542	525
3	12	9	200	220		4	12	4	224	223		5	14	1	24*	112
3	1	10	186	-185		4	14	4	162	142		5	1	2	357	-357
3	3	10	238	-232		4	1	5	234	-226		5	3	2	391	-387

H	K	L	FO	FC	H	K	L	FO	FC	H	K	L	FO	FC
5	5	2	274	269	5	5	10	157*	138	6	7	7	255	262
5	7	2	378	372	5	0	11	0*	81	6	9	7	248	-263
5	9	2	200	-199	5	2	11	163*	164	6	0	8	127	97
5	11	2	324	-320	6	0	0	483	477	6	2	8	217	234
5	13	2	63*	92	6	2	0	46*	35	6	4	8	319	305
5	15	2	274	262	6	4	0	794	772	6	6	8	36*	140
5	0	3	566	545	6	6	0	94	-80	6	8	8	25*	62
5	2	3	25*	66	6	8	0	365	364	6	1	9	238	237
5	4	3	188	190	6	10	0	0*	87	6	3	9	0*	58
5	6	3	20*	3	6	12	0	526	495	6	5	9	0*	-13
5	8	3	410	411	6	14	0	153	-152	6	0	10	188	148
5	10	3	113*	80	6	1	1	490	477	6	2	10	0*	-35
5	12	3	127*	108	6	3	1	448	433	7	0	1	103	110
5	14	3	0*	-39	6	5	1	321	-311	7	2	1	22*	-9
5	1	4	193	165	6	7	1	357	-348	7	4	1	391	389
5	3	4	308	-324	6	9	1	403	385	7	6	1	24*	40
5	5	4	296	297	6	11	1	350	352	7	8	1	34*	88
5	7	4	96	-108	6	13	1	70*	-111	7	10	1	67*	-48
5	9	4	136	145	6	0	2	131	119	7	1	2	258	-254
5	11	4	220	-225	6	2	2	18*	-10	7	3	2	281	-270
5	13	4	182	188	6	4	2	0*	-50	7	5	2	191	187
5	0	5	519	510	6	6	2	27*	54	7	7	2	272	272
5	2	5	41*	62	6	8	2	56*	69	7	9	2	162*	-150
5	4	5	0*	-33	6	10	2	48*	-34	7	11	2	245	-231
5	6	5	0*	-19	6	12	2	0*	-18	7	0	3	581	582
5	8	5	395	393	6	1	3	0*	57	7	2	3	18*	57
5	10	5	58*	106	6	3	3	18*	-78	7	4	3	0*	-85
5	12	5	31*	-24	6	5	3	117*	84	7	6	3	18*	-18
5	1	6	258	253	6	7	3	182	-188	7	8	3	466	474
5	3	6	275	273	6	9	3	53*	-77	7	10	3	151*	94
5	5	6	217	-216	6	11	3	0*	-35	7	1	4	143	139
5	7	6	281	-279	6	13	3	22*	47	7	3	4	195	-198
5	9	6	141*	109	6	0	4	479	-461	7	5	4	196	188
5	11	6	267	243	6	2	4	0*	62	7	7	4	32*	-106
5	13	6	55*	-120	6	4	4	1365	1355	7	9	4	24*	132
5	0	7	56*	-37	6	6	4	113	135	7	0	5	571	567
5	2	7	115	120	6	8	4	381	-379	7	2	5	25*	50
5	4	7	424	424	6	10	4	22*	-52	7	4	5	217	-234
5	6	7	160	154	6	12	4	904	897	7	6	5	72*	-35
5	8	7	0*	-39	6	1	5	131	140	7	8	5	462	466
5	10	7	62*	34	6	3	5	94*	-92	7	1	6	205	205
5	12	7	276	284	6	5	5	46*	88	7	3	6	262	251
5	1	8	317	317	6	7	5	0*	1	7	5	6	179	-199
5	3	8	141	-149	6	9	5	200	202	7	7	6	207	-233
5	5	8	176	182	6	11	5	0*	-69	7	0	7	113	123
5	7	8	283	-279	6	0	6	0*	-59	7	2	7	27*	96
5	9	8	234	252	6	2	6	0*	-51	7	4	7	167	164
5	0	9	327	-327	6	4	6	110	101	7	6	7	36*	100
5	2	9	25*	60	6	6	6	0*	52	7	1	8	303	291
5	4	9	429	424	6	8	6	0*	-62	7	3	8	0*	-66
5	6	9	143	136	6	10	6	27*	-82	8	0	0	1192	1177
5	8	9	253	-274	6	1	7	324	-320	8	2	0	0*	25
5	1	10	176	-192	6	3	7	569	-562	8	4	0	265	-279
5	3	10	217	-219	6	5	7	436	440	8	6	0	44*	-57

H	K	L	FO	FC	H	K	L	FO	FC	H	K	L	FO	FC
8	8	0	977	974	8	6	2	0*	-28	8	6	4	29*	105
8	1	1	0*	23	8	8	2	0*	13	8	1	5	108*	-122
8	3	1	0*	31	8	1	3	388	382	8	3	5	265	-249
8	5	1	51*	75	8	3	3	269	268	8	5	5	300	277
8	7	1	0*	-25	8	5	3	277	-279	8	0	6	115	-91
8	9	1	0*	21	8	7	3	410	-401	8	2	6	29*	-7
8	0	2	0*	5	8	0	4	450	430	9	0	1	136	-154
8	2	2	24*	20	8	2	4	29*	44	9	2	1	0*	-12
8	4	2	48*	-22	8	4	4	233	244	9	1	2	201	-195