Comments on tables of magnetic space groups

Hans Grimmer

Received 26 June 2008

Accepted 20 November 2008

Laboratory for Developments and Methods, Condensed Matter Research with Neutrons and Muons,
Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland. Correspondence e-mail:
hans.grimmer@psi.ch

Litvin [*Acta Cryst.* (2008), **A64**, 419–424 and supplementary material] extends much of the information contained in Volume A of *International Tables for Crystallography* for the 230 space-group types to the 1651 types of Shubnikov space groups, using Opechowski–Guccione (OG) notation for the space groups with a black–white lattice. It is pointed out that OG notation has crucial disadvantages compared to Belov–Neronova–Smirnova (BNS) notation. It is shown how Litvin’s diagrams of symmetry elements for the orthorhombic Shubnikov space groups can be interpreted in terms of BNS symbols and how those containing *e*-glides can be simplified. A number of mistakes in the diagrams of Litvin are corrected.

© 2009 International Union of Crystallography
Printed in Singapore – all rights reserved

1. Introduction

Litvin (2008) published a six-page paper describing his tables of crystallographic properties of magnetic space groups contained in 4472 pages of supplementary material. The tables describe the 7, 80 and 1651 types of Shubnikov space groups in one, two and three dimensions, respectively. Let $\mathbf{G}$ be an ordinary space group, $\mathbf{H}$ a subgroup of index 2 of $\mathbf{G}$ and let $1'$ denote time inversion. Among the 1651 types there are 230 of the form $\mathbf{G}$, 230 of the form $\mathbf{G} + \mathbf{G}1'$ and 1191 of the form $\mathbf{H} + (\mathbf{G} - \mathbf{H})1'$. For 674 among the 1191 types $\mathbf{H}$ is an isotranslational subgroup and for the remaining 517 $\mathbf{H}$ is an isoclass subgroup. In the language of two-colour groups, where $1'$ is interpreted as exchanging black and white (or black and red for typographical reasons), we speak of 230 monochrome types, 230 grey types, 674 black–white types of the first kind and 517 black–white types of the second kind.

Considering a fixed space group $\mathbf{G}$, Litvin (2008), following Opechowski (1986), defines the superfamily of $\mathbf{G}$ consisting of the types containing $\mathbf{G}$, $\mathbf{G} + \mathbf{G}1'$ and $\mathbf{H} + (\mathbf{G} - \mathbf{H})1'$ for all subgroups $\mathbf{H}$ of index 2 in $\mathbf{G}$. Koptsik (1966), following Belov *et al.* (1957*a,b*), proceeded differently: They grouped together the types containing $\mathbf{G}$, $\mathbf{G} + \mathbf{G}1'$, $\mathbf{H} + (\mathbf{G} - \mathbf{H})1'$ for all isotranslational subgroups $\mathbf{H}$ of index 2 in $\mathbf{G}$ and $\mathbf{G} + \mathbf{G}t1'$, where t is a translation not contained in $\mathbf{G}$ but such that $2t$ lies in $\mathbf{G}$. The two definitions group the 1651 types in different ways into 230 ‘superfamilies’. Both classifications have been used to define symbols for the space-group types that let one immediately recognize the superfamily to which the type belongs. They will be referred to as Opechowski–Guccione (OG) and Belov–Neronova–Smirnova (BNS) symbols. The two symbols agree for monochrome, grey and black–white groups of the first kind (BW1) but differ for black–white groups of the second kind (BW2).

Of prime interest in Litvin (2008) are his descriptions of the 1191 black–white space-group types in three dimensions. Whereas the crystal lattice is determined by all translations contained in $\mathbf{G}$, the point group is isomorphic to the factor group $\mathbf{G}/\mathbf{T}$, where $\mathbf{T}$ is the group of colour-preserving translations in $\mathbf{G}$. The 517 BW2 types have a black–white lattice and a grey point group; they describe antiferromagnets. The 674 BW1 types have a monochrome lattice and a black–white point group; 231 of them admit ferromagnetism, the remaining 443 describe antiferromagnets (see *e.g.* Borovik–Romanov & Grimmer, 2003).

Until now the standard work on the 1191 black–white space-group types has been the book by Koptsik (1966), giving for each of these types two diagrams showing a projection of its symmetry elements and of an object in a general position, respectively. Whereas in the diagrams of Koptsik it is often difficult to distinguish between mirror planes and the different kinds of glide planes, Litvin’s analogous diagrams are of high graphical quality. Except for the subgroups and supergroups, most other information that Volume A of *International Tables for Crystallography* (1995) gives for the 230 monochrome types is given by Litvin (2008) in a similar presentation for all 1651 types. Last but not least, most readers will appreciate that Litvin (2008) presents his information in English, whereas Koptsik (1966) used Russian.

The book of Koptsik (1966) being out of print for many years, the gigantic tables of Litvin (2008) are most welcome. In the view of the present author, their main drawback is the use of OG notation. In fact, we shall show that OG notation has decisive disadvantages, which led to the more widespread use of BNS notation. The main aim of the present paper is facilitating the use of Litvin’s tables to those familiar with BNS notation.

As an example, let us compare superfamily 67 in the sense of BNS and in the sense of OG. As stated above, the two

Table 1
The Shubnikov space-group types related to point group 222.

Koptsik (1966)		Litvin (2008)-SM						Notes
BNS No.	BNS symbol	Litvin No.	OG symbol	Page	dir1	dir2	dir3	
16.1	$P222$	16.1.99	$P222$	720	a	b	c	
16.2	$P2221'$	16.2.100	$P2221'$	722	a	b	c	
16.3	$P2'2'2$	16.3.101	$P2'2'2$	724	a	b	c	
16.4	P_a222	16.4.102	$P_{2a}222$	726	$a/2$	b	c	
16.5	P_c222	21.6.134	C_p222	790	a	b	c	
16.6	P_f222	23.4.148	I_p222	818	a	b	c	
17.7	$P222_1$	17.1.106	$P222_1$	734	a	b	c	
17.8	$P222_11'$	17.2.107	$P222_11'$	736	a	b	c	
17.9	$P2'2'2_1$	17.3.108	$P2'2'2_1$	738	a	b	c	
17.10	$P22'2'_1$	17.4.109	$P22'2'_1$	740	a	b	c	
17.11	P_a222_1	17.5.110	$P_{2a}222_1$	742	$a/2$	b	c	
17.12	P_c222_1	16.7.105	$P_{2c}22'2'$	732	a	b	$c/2$	
17.13	P_A222_1	21.10.138	$C_p22'2'$	798	b	c	a	(1)
17.14	P_c222_1	20.5.126	C_p222_1	774	a	b	c	
17.15	P_f222_1	24.5.154	$I_{p2}2'_12'_1$	830	a	b	c	
18.16	$P2_12_12$	18.1.113	$P2_12_12$	748	a	b	c	
18.17	$P2_12_121'$	18.2.114	$P2_12_121'$	750	a	b	c	
18.18	$P2'_12'_12$	18.3.115	$P2'_12'_12$	752	a	b	c	
18.19	$P2_12_12'$	18.4.116	$P2_12_12'$	754	a	b	c	
18.20	$P_a2_12_12$	17.7.112	$P_{2a}2'2'_12_1$	746	$a/2$	c	b	
18.21	$P_c2_12_12$	18.5.117	$P_{2c}2_12_12$	756	a	b	$c/2$	(2)
18.22	$P_A2_12_12$	20.7.128	$C_p22'2'_12'$	778	c	b	a	
18.23	$P_C2_12_12$	21.9.137	$C_p2'2'2$	796	a	b	c	
18.24	$P_f2_12_12$	23.5.149	$I_{p2}2'2'2$	820	a	b	c	
19.25	$P2_12_12_1$	19.1.119	$P2_12_12_1$	760	a	b	c	
19.26	$P2_12_12_11'$	19.2.120	$P2_12_12_11'$	762	a	b	c	
19.27	$P2'_12'_12_1$	19.3.121	$P2'_12'_12_1$	764	a	b	c	
19.28	$P_a2_12_12_1$	18.6.118	$P_{2c}2_12_12'_12'$	758	b	c	$a/2$	
19.29	$P_C2_12_12_1$	20.6.127	$C_p2'2'2_1$	776	a	b	c	
19.30	$P_f2_12_12_1$	24.4.153	$I_{p2}2_12_12_1$	828	a	b	c	
20.31	$C222_1$	20.1.122	$C222_1$	766	a	b	c	
20.32	$C222_11'$	20.2.123	$C222_11'$	768	a	b	c	
20.33	$C2'2'2_1$	20.3.124	$C2'2'2_1$	770	a	b	c	
20.34	$C22'2'_1$	20.4.125	$C22'2'_1$	772	a	b	c	
20.35	C_c222_1	21.8.136	$C_{2c}22'2'$	794	a	b	$c/2$	
20.36	C_a222_1	17.6.111	P_C222_1	744	$a/2$	$b/2$	c	
20.37	C_A222_1	22.5.144	$F_C22'2'$	810	a	b	c	
21.38	$C222$	21.1.129	$C222$	780	a	b	c	
21.39	$C2221'$	21.2.130	$C2221'$	782	a	b	c	
21.40	$C2'2'2$	21.3.131	$C2'2'2$	784	a	b	c	
21.41	$C22'2'$	21.4.132	$C22'2'$	786	a	b	c	
21.42	C_c222	21.5.133	$C_{2c}222$	788	a	b	$c/2$	
21.43	C_a222	16.5.103	P_C222	728	$a/2$	$b/2$	c	
21.44	C_A222	22.4.143	F_C222	808	a	b	c	
22.45	$F222$	22.1.140	$F222$	802	a	b	c	
22.46	$F2221'$	22.2.141	$F2221'$	804	a	b	c	
22.47	$F2'2'2$	22.3.142	$F2'2'2$	806	a	b	c	
22.48	F_s222	16.6.104	P_f222	730	$a/2$	$b/2$	$c/2$	
23.49	$I222$	23.1.145	$I222$	812	a	b	c	
23.50	$I2221'$	23.2.146	$I2221'$	814	a	b	c	
23.51	$I2'2'2$	23.3.147	$I2'2'2$	816	a	b	c	
23.52	I_c222	21.7.135	C_f222	792	a	b	$c/2$	
24.53	$I2_12_12_1$	24.1.150	$I2_12_12_1$	822	a	b	c	
24.54	$I2_12_12_11'$	24.2.151	$I2_12_12_11'$	824	a	b	c	
24.55	$I2'_12'_12_1$	24.3.152	$I2'_12'_12_1$	826	a	b	c	
24.56	$I_c2_12_12_1$	21.11.139	$C_f2'2'2'$	800	a	b	$c/2$	

Notes. (1) Litvin (2008)-SM, dir1: black and red exchanged; (2) Koptsik (1966): diagram of symmetry elements wrong.

Table 2The BW2 space-group types related to point group $mm2$.

Koptsik (1966)		Litvin (2008)-SM						Remarks [L = Litvin (2008)-SM, K = Koptsik (1966)]
BNS No.	BNS symbol	Litvin No.	OG symbol	Page	dir1	dir2	dir3	
25.61	P_cmm2	25.5.159	$P_{2c}mm2$	840	a	b	$c/2$	K: horizontal red c -glide should be an n -glide
25.62	P_bmm2	25.6.160	$P_{2b}mm2$	842	$a/2$	b	c	
25.63	P_cmm2	35.6.241	C_Pmm2	1004	a	b	c	
25.64	P_Amm2	38.7.271	A_Pmm2	1064	a	b	c	
25.65	P_Pmm2	44.5.328	I_Pmm2	1178	a	b	c	
26.71	P_cmc2_1	26.6.173	$P_{2c}mc2_1$	868	$a/2$	b	c	K, dir1: red mirror should be a c -glide
26.72	P_bmc2_1	26.7.174	$P_{2b}mc2_1$	870	a	$b/2$	c	
26.73	P_cmc2_1	25.10.164	$P_{2c}mc'2_1'$	850	a	b	$c/2$	
26.74	P_Amc2_1	38.11.275	$A_Pmm'2'$	1072	a	b	c	
26.75	P_Bmc2_1	39.11.288	$A_Pbm'2'$	1098	b	a	c	
26.76	P_Cmc2_1	36.6.254	C_Pmc2_1	1030	a	b	c	L: black and red exchanged for the mirror and glide planes
26.77	P_Pmc2_1	46.8.345	$I_Pma'2'$	1212	a	b	c	
27.82	P_ccc2	25.11.165	$P_{2c}m'm'2$	852	a	b	$c/2$	
27.83	P_bcc2	27.5.182	$P_{2b}ccc2$	886	$a/2$	b	c	
27.84	P_ccc2	37.5.262	C_Pccc2	1046	a	b	c	
27.85	P_Accc2	39.12.289	$A_Pb'm'2$	1100	a	b	c	
27.86	P_Pccc2	45.5.335	I_Pba2	1192	a	b	c	
28.92	P_pma2	25.12.166	$P_{2b}m'm'2$	854	$a/2$	b	c	
28.93	P_bma2	28.6.190	$P_{2b}ma2$	902	a	$b/2$	c	
28.94	P_pma2	28.7.191	$P_{2c}ma2$	904	a	b	$c/2$	
28.95	P_Ama2	40.6.296	A_Pma2	1114	a	b	c	
28.96	P_Bma2	39.7.284	A_Pbm2	1090	b	a	c	
28.97	P_Cma2	35.10.245	$C_Pm'm2'$	1012	b	a	c	
28.98	P_Pma2	46.6.343	I_Pma2	1208	a	b	c	
29.104	P_aca2_1	26.10.177	$P_{2b}m'c'2_1$	876	b	$a/2$	c	
29.105	P_bca2_1	29.6.203	$P_{2b}ca2_1$	928	a	$b/2$	c	
29.106	P_cca2_1	28.10.194	$P_{2c}m'a2'$	910	a	b	$c/2$	
29.107	P_Aca2_1	41.7.306	$A_Pb'a2'$	1134	a	b	c	
29.108	P_Bca2_1	39.10.287	$A_Pbm'2'$	1096	b	a	c	
29.109	P_Cca2_1	36.7.255	$C_Pm'c2_1'$	1032	b	a	c	L: black and red exchanged for the mirror and glide planes
29.110	P_Pca2_1	45.6.336	$I_Pba'2'$	1194	a	b	c	
30.116	P_pnc2	30.6.210	$P_{2c}nc2$	942	$a/2$	b	c	
30.117	P_bnc2	27.7.184	$P_{2b}c'c2'$	890	a	$b/2$	c	
30.118	P_cnc2	28.12.196	$P_{2c}m'a'2$	914	b	a	$c/2$	
30.119	P_Anc2	38.12.276	$A_Pm'm'2$	1074	a	b	c	K: diagram of symmetry elements wrong K, dir1: red c -glide missing
30.120	P_Bnc2	41.9.308	$A_Pb'a'2$	1138	b	a	c	
30.121	P_Cnc2	37.6.263	$C_Pc'c2'$	1048	a	b	c	
30.122	P_Pnc2	46.9.346	$I_Pm'a'2$	1214	a	b	c	
31.128	P_pmn2_1	26.9.176	$P_{2c}mc'2_1'$	874	$a/2$	b	c	K, dir2: one black n -glide missing
31.129	P_bmn2_1	31.6.217	$P_{2b}mn2_1$	956	a	$b/2$	c	
31.130	P_pmn2_1	28.11.195	$P_{2c}ma'2'$	912	a	b	$c/2$	
31.131	P_Amn2_1	40.8.298	$A_Pma'2'$	1118	a	b	c	
31.132	P_Bmn2_1	38.10.274	$A_Pm'm2'$	1070	b	a	c	
31.133	P_Cmn2_1	36.8.256	$C_Pmc'2_1'$	1034	a	b	c	
31.134	P_Pmn2_1	44.6.329	$I_Pmm'2'$	1180	a	b	c	
32.139	P_cba2	32.5.223	$P_{2c}ba2$	968	a	b	$c/2$	
32.140	P_bba2	28.9.193	$P_{2b}m'a2'$	908	b	$a/2$	c	
32.141	P_cba2	35.11.246	$C_Pm'm'2$	1014	a	b	c	
32.142	P_Aba2	41.6.305	A_Pba2	1132	a	b	c	
32.143	P_Pba2	45.7.337	$I_Pb'a'2$	1196	a	b	c	
33.149	P_pna2_1	31.7.218	$P_{2b}m'n2_1'$	958	b	$a/2$	c	
33.150	P_bna2_1	29.7.204	$P_{2b}c'a'2_1$	930	a	$b/2$	c	
33.151	P_pna2_1	32.6.224	$P_{2c}b'a2'$	970	a	b	$c/2$	
33.152	P_Ana2_1	40.7.297	$A_Pm'a2'$	1116	a	b	c	K, dir2: red mirror planes missing
33.153	P_Bna2_1	41.8.307	$A_Pba'2'$	1136	b	a	c	
33.154	P_Cna2_1	36.9.257	$C_Pm'c'2_1$	1036	b	a	c	
33.155	P_Pna2_1	46.7.344	$I_Pm'a2'$	1210	a	b	c	
34.160	P_pnn2	30.7.211	$P_{2c}nc'2'$	944	$a/2$	b	c	K, dir2: red n -glides should be omitted
34.161	P_pnn2	32.7.225	$P_{2c}b'a'2$	972	a	b	$c/2$	
34.162	P_Ann2	40.9.299	$A_Pm'a'2$	1120	a	b	c	
34.163	P_Cnn2	37.7.264	$C_Pc'c'2$	1050	a	b	c	
34.164	P_Pnn2	44.7.330	$I_Pm'm'2$	1182	a	b	c	

Table 2 (continued)

Koptsik (1966)		Litvin (2008)-SM						Remarks [L = Litvin (2008)-SM, K = Koptsik (1966)]
BNS No.	BNS symbol	Litvin No.	OG symbol	Page	dir1	dir2	dir3	
35.169	$C_{2v}mm2$	35.5.240	$C_{2v}mm2$	1002	a	b	$c/2$	
35.170	$C_{2v}mm2$	25.7.161	$P_{C2v}mm2$	844	$a/2$	$b/2$	c	
35.171	$C_{2v}mm2$	42.5.313	$F_{C2v}mm2$	1148	a	b	c	
36.177	$C_{2v}mc2_1$	35.8.243	$C_{2v}m'm'2'$	1008	b	a	$c/2$	
36.178	$C_{2v}mc2_1$	26.8.175	$P_{C2v}mc2_1$	872	$a/2$	$b/2$	c	
36.179	$C_{2v}mc2_1$	42.7.315	$F_{C2v}mm'2'$	1152	a	b	c	
37.184	$C_{2v}cc2$	35.9.244	$C_{2v}m'm'2$	1010	a	b	$c/2$	
37.185	$C_{2v}cc2$	27.6.183	$P_{C2v}cc2$	888	$a/2$	$b/2$	c	
37.186	$C_{2v}cc2$	42.8.316	$F_{C2v}m'm'2$	1154	a	b	c	
38.192	$A_{2v}mm2$	38.6.270	$A_{2v}mm2$	1062	$a/2$	b	c	K, dir1: red mirror planes missing; L, dir1: omit n -glides
38.193	$A_{2v}mm2$	25.8.162	$P_{A2v}mm2$	846	a	$b/2$	$c/2$	dir1: replace c -glides by e -glides; K, dir2: red mirror planes missing
38.194	$A_{2v}mm2$	42.6.314	$F_{A2v}mm2$	1150	a	b	c	K, dir1: red e -glides missing; L, dir1: omit n -glides, replace axial glides by e -glides
39.200	$A_{2v}bm2$	39.6.283	$A_{2v}bm2$	1088	$a/2$	b	c	dir1: replace axial glides by e -glides
39.201	$A_{2v}bm2$	25.13.167	$P_{A2v}m'm'2$	856	a	$b/2$	$c/2$	dir1: replace axial glides by e -glides; K, dir1: replace n -glides by mirrors
39.202	$A_{2v}bm2$	42.9.317	$F_{A2v}m'm'2'$	1156	a	b	c	dir1: replace axial glides by e -glides; L, dir1: omit n -glides
40.208	$A_{2v}ma2$	38.9.273	$A_{2v}mm'm'2'$	1068	$a/2$	b	c	L, dir1: omit n -glides
40.209	$A_{2v}ma2$	28.8.192	$P_{A2v}ma2$	906	a	$b/2$	$c/2$	dir1: replace axial glides by e -glides
40.210	$A_{2v}ma2$	42.10.318	$F_{A2v}mm'm'2'$	1158	a	b	c	dir1: replace axial glides by e -glides; L, dir1: omit n -glides
41.216	$A_{2v}ba2$	39.9.286	$A_{2v}b'm'2$	1094	$a/2$	b	c	dir1: replace axial glides by e -glides; L, dir3: rotations and screws in top and bottom rows should be black, in middle row red
41.217	$A_{2v}ba2$	28.13.197	$P_{A2v}m'a'2$	916	a	$b/2$	$c/2$	dir1: replace axial glides by e -glides
41.218	$A_{2v}ba2$	42.11.319	$F_{A2v}m'm'2$	1160	a	b	c	dir1: replace axial glides by e -glides; L, dir1: omit n -glides
42.223	$F_{2v}mm2$	25.9.163	$P_{F2v}mm2$	848	$a/2$	$b/2$	$c/2$	replace glide planes by e -glides
43.228	$F_{2v}dd2$	34.5.235	$P_{F2v}nn2$	992	$a/2$	$b/2$	$c/2$	
44.233	$I_{2v}mm2$	35.7.242	$C_{I2v}mm2$	1006	a	b	$c/2$	
44.234	$I_{2v}mm2$	38.8.272	$A_{I2v}mm2$	1066	$a/2$	b	c	
45.239	$I_{2v}ba2$	35.13.248	$C_{I2v}m'm'2$	1018	a	b	$c/2$	
45.240	$I_{2v}ba2$	39.13.290	$A_{I2v}b'm'2$	1102	$a/2$	b	c	
46.246	$I_{2v}ma2$	35.12.247	$C_{I2v}m'm'2'$	1016	a	b	$c/2$	
46.247	$I_{2v}ma2$	38.13.277	$A_{I2v}m'm'2$	1076	$a/2$	b	c	L, dir2: red c -glide should be black, black n -glide should be red
46.248	$I_{2v}ma2$	39.8.285	$A_{I2v}bm2$	1092	$b/2$	a	c	

superfamilies contain the same monochrome type ($Cmma$), the same grey type ($Cmma1'$) and the same black–white types of the first kind ($Cm'ma$, $Cmma'$, $Cm'm'a$, $Cmm'a'$, $Cm'm'a'$). Superfamily 67 in the sense of BNS contains in addition the following BW2 types: $C_{2v}mma$, $C_{2v}mma$ and $C_{2v}mma$. Their monochrome subgroups are of type $Cmma$. Starting with the diagram of symmetry elements for $Cmma$, the ones for $C_{2v}mma$, $C_{2v}mma$ and $C_{2v}mma$ are easily obtained by combining each symmetry element in the diagram for $Cmma$ with a subsequent colour-changing translation by $c/2$, $a/2$ and $b/2 + c/2$, respectively. Similarly, the general-position diagrams for $C_{2v}mma$, $C_{2v}mma$ and $C_{2v}mma$ are obtained by applying to each position in the diagram for $Cmma$ a colour-changing translation by $c/2$, $a/2$ and $b/2 + c/2$, respectively. In the general case, there are 16 positions equivalent under $Cmma$. For 8 of them the coordinate triplets are given explicitly in *International Tables* as a $(0, 0, 0)+$ set, the other 8 being obtained by adding $(\frac{1}{2}, \frac{1}{2}, 0)$. For the interpretation of the BNS symbol it does not matter how the 16 positions are split into a $(0, 0, 0)+$ and a

$(\frac{1}{2}, \frac{1}{2}, 0)+$ set because the objects in all 16 positions have the same colour. Superfamily 67 in the sense of OG contains the following BW2 types: $C_{2v}mma$, $C_{2v}m'm'a$, $C_{2v}m'm'a$, $C_{2v}mma$, $C_{2v}m'm'a$, $C_{2v}m'm'a$, $C_{2v}m'm'a$, $C_{2v}m'm'a$ and $C_{2v}m'm'a$. Whereas different BW2 types in a BNS superfamily have different centring symbols and never contain primes, different BW2 types in an OG superfamily may have the same centring symbol but a different arrangement of primes. The meaning of the centring symbols differs in BNS and OG notation: Whereas in BNS notation the C -centred orthorhombic cell is spanned by unprimed translations $a/2 + b/2$, b and c , in OG notation it is spanned by $a/2 + b/2$, b and c' for C_{2v} , by $a'/2 + b'/2$, b and c for C_p , and by $a'/2 + b'/2$, b and c' for C_r . The elements in the OG symbol to the right of the centring subscript denote operations mapping position x, y, z into a position in the $(0, 0, 0)+$ set. The objects at these two positions have the same colour if the element is unprimed and different colours if the element is primed. Now it matters how the

Table 3

The monochrome, grey and BW1 space-group types related to point group *mm*2.

BNS No.	Symbol	Litvin No.	Page	Notes
25.57	<i>Pmm</i> 2	25.1.155	832	
25.58	<i>Pmm</i> 21'	25.2.156	834	
25.59	<i>Pm'</i> m2'	25.3.157	836	
25.60	<i>Pm'</i> m'2	25.4.158	838	
26.66	<i>Pmc</i> 2 ₁	26.1.168	858	
26.67	<i>Pmc</i> 2 ₁ 1'	26.2.169	860	
26.68	<i>Pm'</i> c2 ₁ '	26.3.170	862	
26.69	<i>Pmc'</i> 2 ₁ '	26.4.171	864	
26.70	<i>Pm'</i> c'2 ₁	26.5.172	866	
27.78	<i>Pcc</i> 2	27.1.178	878	
27.79	<i>Pcc</i> 21'	27.2.179	880	
27.80	<i>Pc'</i> c2'	27.3.180	882	
27.81	<i>Pc'</i> c'2	27.4.181	884	
28.87	<i>Pma</i> 2	28.1.185	892	
28.88	<i>Pma</i> 21'	28.2.186	894	
28.89	<i>Pm'</i> a2'	28.3.187	896	
28.90	<i>Pma'</i> 2'	28.4.188	898	
28.91	<i>Pm'</i> a'2	28.5.189	900	
29.99	<i>Pca</i> 2 ₁	29.1.198	918	
29.100	<i>Pca</i> 2 ₁ 1'	29.2.199	920	
29.101	<i>Pc'</i> a2 ₁ '	29.3.200	922	(1)
29.102	<i>Pca'</i> 2 ₁ '	29.4.201	924	(2)
29.103	<i>Pc'</i> a'2 ₁	29.5.202	926	
30.111	<i>Pnc</i> 2	30.1.205	932	
30.112	<i>Pnc</i> 21'	30.2.206	934	
30.113	<i>Pn'</i> c2'	30.3.207	936	
30.114	<i>Pnc'</i> 2'	30.4.208	938	
30.115	<i>Pn'</i> c'2	30.5.209	940	
31.123	<i>Pmn</i> 2 ₁	31.1.212	946	
31.124	<i>Pmn</i> 2 ₁ 1'	31.2.213	948	
31.125	<i>Pm'</i> n2 ₁ '	31.3.214	950	
31.126	<i>Pmn'</i> 2 ₁ '	31.4.215	952	
31.127	<i>Pm'</i> n'2 ₁	31.5.216	954	
32.135	<i>Pba</i> 2	32.1.219	960	
32.136	<i>Pba</i> 21'	32.2.220	962	
32.137	<i>Pb'</i> a2'	32.3.221	964	
32.138	<i>Pb'</i> a'2	32.4.222	966	
33.144	<i>Pna</i> 2 ₁	33.1.226	974	
33.145	<i>Pna</i> 2 ₁ 1'	33.2.227	976	
33.146	<i>Pn'</i> a2 ₁ '	33.3.228	978	
33.147	<i>Pna'</i> 2 ₁ '	33.4.229	980	
33.148	<i>Pn'</i> a'2 ₁	33.5.230	982	
34.156	<i>Pnn</i> 2	34.1.231	984	
34.157	<i>Pnn</i> 21'	34.2.232	986	
34.158	<i>Pn'</i> n2'	34.3.233	988	
34.159	<i>Pn'</i> n'2	34.4.234	990	
35.165	<i>Cmm</i> 2	35.1.236	994	
35.166	<i>Cmm</i> 21'	35.2.237	996	
35.167	<i>Cm'</i> m2'	35.3.238	998	
35.168	<i>Cm'</i> m'2	35.4.239	1000	
36.172	<i>Cmc</i> 2 ₁	36.1.249	1020	
36.173	<i>Cmc</i> 2 ₁ 1'	36.2.250	1022	
36.174	<i>Cm'</i> c2 ₁ '	36.3.251	1024	
36.175	<i>Cmc'</i> 2 ₁ '	36.4.252	1026	
36.176	<i>Cm'</i> c'2 ₁	36.5.253	1028	
37.180	<i>Ccc</i> 2	37.1.258	1038	
37.181	<i>Ccc</i> 21'	37.2.259	1040	
37.182	<i>Cc'</i> c2'	37.3.260	1042	(3)
37.183	<i>Cc'</i> c'2	37.4.261	1044	
38.187	<i>Amm</i> 2	38.1.265	1052	
38.188	<i>Amm</i> 21'	38.2.266	1054	
38.189	<i>Am'</i> m2'	38.3.267	1056	(4)

Table 3 (continued)

BNS No.	Symbol	Litvin No.	Page	Notes
38.190	<i>Amm'</i> 2'	38.4.268	1058	(5)
38.191	<i>Am'</i> m'2	38.5.269	1060	(4)
39.195	<i>Abm</i> 2	39.1.278	1078	(6)
39.196	<i>Abm</i> 21'	39.2.279	1080	(6)
39.197	<i>Ab'</i> m2'	39.3.280	1082	(7)
39.198	<i>Abm'</i> 2'	39.4.281	1084	(6)
39.199	<i>Ab'</i> m'2	39.5.282	1086	(7)
40.203	<i>Ama</i> 2	40.1.291	1104	(5)
40.204	<i>Ama</i> 21'	40.2.292	1106	(5)
40.205	<i>Am'</i> a2'	40.3.293	1108	(4)
40.206	<i>Ama'</i> 2'	40.4.294	1110	(5)
40.207	<i>Am'</i> a'2	40.5.295	1112	(4)
41.211	<i>Aba</i> 2	41.1.300	1122	(6)
41.212	<i>Aba</i> 21'	41.2.301	1124	(6)
41.213	<i>Ab'</i> a2'	41.3.302	1126	(7)
41.214	<i>Aba'</i> 2'	41.4.303	1128	(6)
41.215	<i>Ab'</i> a'2	41.5.304	1130	(7)
42.219	<i>Fmm</i> 2	42.1.309	1140	(8), (9)
42.220	<i>Fmm</i> 21'	42.2.310	1142	(8), (9)
42.221	<i>Fm'</i> m2'	42.3.311	1144	(8), (9)
42.222	<i>Fm'</i> m'2	42.4.312	1146	(8), (9)
43.224	<i>Fdd</i> 2	43.1.320	1162	
43.225	<i>Fdd</i> 21'	43.2.321	1164	
43.226	<i>Fd'</i> d2'	43.3.322	1166	
43.227	<i>Fd'</i> d'2	43.4.323	1168	
44.229	<i>Imm</i> 2	44.1.324	1170	
44.230	<i>Imm</i> 21'	44.2.325	1172	
44.231	<i>Im'</i> m2'	44.3.326	1174	
44.232	<i>Im'</i> m'2	44.4.327	1176	
45.235	<i>Iba</i> 2	45.1.331	1184	
45.236	<i>Iba</i> 21'	45.2.332	1186	
45.237	<i>Ib'</i> a2'	45.3.333	1188	(10)
45.238	<i>Ib'</i> a'2	45.4.334	1190	
46.241	<i>Ima</i> 2	46.1.338	1198	
46.242	<i>Ima</i> 21'	46.2.339	1200	
46.243	<i>Im'</i> a2'	46.3.340	1202	
46.244	<i>Ima'</i> 2'	46.4.341	1204	
46.245	<i>Im'</i> a'2	46.5.342	1206	

Notes. (1) Koptsik (1966): diagrams of symmetry elements unclear; (2) Koptsik (1966): diagrams of symmetry elements misleading; (3) Litvin (2008)-SM: screws should be rotations; (4) Litvin (2008)-SM, dir1: omit red *n*-glide; (5) Litvin (2008)-SM, dir1: omit black *n*-glide; (6) dir1: replace axial glides by black *e*-glide; (7) dir1: replace axial glides by red *e*-glide; (8) Litvin (2008)-SM: omit all *n*-glides; (9) replace axial glides by *e*-glide of the same colour; (10) Litvin (2008)-SM shows *Iba'*2' not *Ib'a'*2'.

triplets for the general position are split into various sets when the conventional lattice is centred. Originally, the meaning of the OG symbols was based on the choice made in Volume I of *International Tables for X-ray Crystallography* (1952), which will be referred to as ITXC52. Taking instead the choice made in Volume A of *International Tables for Crystallography* (1983) (which will be referred to as ITC83) as proposed by Litvin (1998), primed and unprimed have to be interchanged in superfamily 67 for *a* and the second *m* in the cases of *C_P* and *C_I* according to Table 2 in Litvin (1998). Because this means that one has to specify the edition of *International Tables* underlying the symbol, Litvin (2001) proposed returning to the original definition of the OG symbols. Whereas ITXC52 or the 216-page supplementary material to Litvin (2001) has to be consulted for interpreting the OG symbols of BW2 types,

Table 4The BW2 space-group types related to point group *mmm*.

Koptsik (1966)		Litvin (2008)-SM						Remarks [L = Litvin (2008)-SM, K = Koptsik (1966)]
BNS No.	BNS symbol	Litvin No.	OG symbol	Page	dir1	dir2	dir3	
47.254	P_6mmm	47.6.352	$P_{2a}mmm$	1231	$a/2$	b	c	
47.255	P_6mmmm	65.9.553	C_Pmmmm	1642	a	b	c	
47.256	P_6mmmm	71.6.626	I_Pmmmm	1790	a	b	c	
48.262	P_6nnn	50.10.386	$P_{2c}b'a'n$	1306	b	c	$a/2$	K shows P_6nnn [in accord with Belov <i>et al.</i> (1957 <i>a,b</i>)] not P_6nnn
48.263	P_6nnn	66.13.576	$C_Pc'c'm'$	1688	a	b	c	
48.264	P_6nnn	71.9.629	$I_Pm'm'm'$	1796	a	b	c	L: Screws should be red, inversions on them black
49.272	P_6ccm	49.8.361	$P_{2a}ccm$	1276	$a/2$	b	c	
49.273	P_6ccm	47.10.356	$P_{2c}m'm'm$	1243	a	b	$c/2$	L: red screws should be at height 1/4
49.274	P_6ccm	67.9.585	C_Pmma	1706	c	b	a	
49.275	P_6ccm	66.8.571	C_Pccm	1678	a	b	c	
49.276	P_6ccm	72.8.637	I_Pbam	1812	a	b	c	
50.284	P_6ban	49.12.375	$P_{2a}c'c'm'$	1284	$a/2$	c	b	
50.285	P_6ban	50.8.384	$P_{2c}ban$	1302	a	b	$c/2$	
50.286	P_6ban	68.8.601	C_Pcca	1738	c	b	a	
50.287	P_6ban	65.17.561	$C_Pm'm'm'$	1658	a	b	c	
50.288	P_6ban	72.13.642	$I_Pb'a'm'$	1822	a	b	c	K: red rotations in dir3 should be screws
51.298	P_6mma	47.9.355	$P_{2a}mmmm'$	1240	$a/2$	b	c	
51.299	P_6mma	51.10.396	$P_{2b}mma$	1326	a	$b/2$	c	
51.300	P_6mma	51.11.397	$P_{2c}mma$	1328	a	b	$c/2$	
51.301	P_6mma	63.10.520	C_Pmcm	1576	b	c	a	L, dir3: screws on black mirror planes and inversions on them should be black
51.302	P_6mma	65.13.557	$C_Pm'mm$	1650	c	a	b	K, dir3: red rotations should be screws
51.303	P_6mma	67.14.590	$C_Pmm'a$	1716	a	b	c	K, dir2: red screws missing
51.304	P_6mma	74.8.657	I_Pmma	1852	b	a	c	K, dir3: red rotations should be screws
52.314	P_6nna	53.13.427	$P_{2b}m'na'$	1390	c	$a/2$	b	K: there should be no mirror planes in dir2
52.315	P_6nna	50.9.385	$P_{2c}b'an$	1304	a	c	$b/2$	
52.316	P_6nna	54.13.440	$P_{2b}c'ca'$	1416	b	$c/2$	a	
52.317	P_6nna	66.12.575	$C_Pcc'm'$	1686	c	b	a	
52.318	P_6nna	63.17.527	$C_Pm'c'm'$	1590	c	a	b	
52.319	P_6nna	68.11.604	$C_Pcc'a'$	1744	a	b	c	K: the red <i>n</i> -glides should be omitted
52.320	P_6nna	74.9.658	$I_Pm'm'a$	1854	b	a	c	K: the red <i>n</i> -glides should be omitted
53.330	P_6nna	51.15.401	$P_{2b}m'ma'$	1337	c	$a/2$	b	
53.331	P_6nna	53.10.424	$P_{2b}mna$	1384	a	$b/2$	c	L, dir2: rotations should be at height 1/4
53.332	P_6nna	49.11.374	$P_{2a}c'c'm$	1282	$c/2$	b	a	
53.333	P_6nna	66.9.572	$C_Pc'cm$	1680	b	c	a	
53.334	P_6nna	65.16.560	$C_Pmm'm'$	1656	a	c	b	
53.335	P_6nna	64.15.542	$C_Pmc'a'$	1620	a	b	c	K, dir1: black rotations missing
53.336	P_6nna	74.10.659	$I_Pmm'a'$	1856	a	b	c	
54.346	P_6cca	49.10.373	$P_{2a}ccm'$	1280	$a/2$	b	c	
54.347	P_6cca	54.10.437	$P_{2b}cca$	1410	a	$b/2$	c	
54.348	P_6cca	51.18.404	$P_{2c}m'm'a$	1343	a	b	$c/2$	K, dir1: black screws are at height 1/4 (indicated only above diagram of symmetry elements)
54.349	P_6cca	64.11.538	$C_Pm'ca$	1612	b	c	a	
54.350	P_6cca	67.13.589	$C_Pm'ma$	1714	c	a	b	
54.351	P_6cca	68.9.602	$C_Pc'ca$	1740	b	a	c	
54.352	P_6cca	73.7.649	$I_Pb'ca$	1836	a	b	c	L, dir1: rotations should be red, screws should be black
55.360	P_6bam	51.16.402	$P_{2c}m'ma$	1339	b	c	$a/2$	
55.361	P_6bam	55.8.448	$P_{2c}bam$	1432	a	b	$c/2$	L, dir1: axial glide should be black, mirror red
55.362	P_6bam	64.10.537	C_Pmca	1610	c	b	a	
55.363	P_6bam	65.15.559	$C_Pm'm'm$	1654	a	b	c	
55.364	P_6bam	72.11.640	$I_Pb'a'm$	1818	a	b	c	
56.372	P_6ccn	54.12.439	$P_{2b}cca'$	1414	b	$a/2$	c	K, dir2: red <i>n</i> -glide plane missing
56.373	P_6ccn	59.10.487	$P_{2c}m'm'n$	1510	a	b	$c/2$	
56.374	P_6ccn	64.14.541	$C_Pm'c'a$	1618	b	c	a	
56.375	P_6ccn	66.10.573	C_Pccm'	1682	a	b	c	
56.376	P_6ccn	72.10.639	I_Pbam'	1816	a	b	c	
57.386	P_6bcm	57.10.467	$P_{2a}bcm$	1470	$a/2$	b	c	
57.387	P_6bcm	51.17.403	$P_{2c}mm'a$	1341	c	a	$b/2$	
57.388	P_6bcm	51.13.399	$P_{2b}m'ma$	1333	b	$c/2$	a	
57.389	P_6bcm	67.15.591	C_Pmma'	1718	c	b	a	L, dir3: glide planes have wrong colour
57.390	P_6bcm	64.13.540	C_Pmca'	1616	c	a	b	
57.391	P_6bcm	63.11.521	$C_Pm'cm$	1578	a	b	c	L: half of the inversions and of the screws in dir3 should be black

Table 4 (continued)

Koptsik (1966)		Litvin (2008)-SM						Remarks [L = Litvin (2008)-SM, K = Koptsik (1966)]
BNS No.	BNS symbol	Litvin No.	OG symbol	Page	dir1	dir2	dir3	
57.392	P_1bcm	72.9.638	$I_{pb'}am$	1814	a	b	c	
58.400	P_2nnm	53.12.426	$P_{2b}mna'$	1388	c	$a/2$	b	L: red (not black) inversion points lie at height 1/2
58.401	P_2nnm	55.10.450	$P_{2c}b'a'm$	1436	a	b	$c/2$	
58.402	P_2nnm	63.15.525	$C_{pmc'}m'$	1586	c	b	a	
58.403	P_2nnm	66.11.574	$C_{pc'}c'm$	1684	a	b	c	
58.404	P_2nnm	71.8.628	$I_{pm'}m'm$	1794	a	b	c	
59.412	P_2nmn	51.14.400	$P_{2b}mma'$	1335	b	$a/2$	c	K: inversion on black rotation should be red L, dir2: n -glides should be red
59.413	P_2nmn	59.8.485	$P_{2c}mmn$	1506	a	b	$c/2$	
59.414	P_2nmn	63.12.522	$C_{pmc'}m$	1580	b	c	a	
59.415	P_2nmn	65.14.558	$C_{pmm}m'$	1652	a	b	c	
59.416	P_2nmn	71.7.627	$I_{pm'}mm$	1792	c	a	b	
60.426	P_2bcn	54.11.438	$P_{2b}c'ca$	1412	c	$a/2$	b	K, dir1: red axial glide planes missing
60.427	P_2bcn	57.13.470	$P_{2a}bc'm'$	1476	$b/2$	c	a	
60.428	P_2bcn	53.11.425	$P_{2b}m'na$	1386	b	$c/2$	a	
60.429	P_2bcn	64.17.544	$C_{pm'}c'a'$	1624	b	c	a	
60.430	P_2bcn	68.10.603	$C_{pcc}d'$	1742	c	a	b	
60.431	P_2bcn	63.16.526	$C_{pm'}cm'$	1588	a	b	c	K, dir2: red axial glide planes missing
60.432	P_2bcn	72.12.641	$I_{pb'}am'$	1820	a	b	c	
61.438	P_2bca	57.12.469	$P_{2a}bcm'$	1474	$a/2$	b	c	K, dir2: red n -glide planes missing
61.439	P_2bca	64.16.543	$C_{pm'}ca'$	1622	a	b	c	
61.440	P_2bca	73.6.648	I_{pbca}	1834	a	b	c	K, dir2: red rotations lie at height 0
62.450	P_2nma	59.9.486	$P_{2c}m'mn$	1508	c	b	$a/2$	L & K: omit n -glides in dir3 L, dir1: no black n -glide, red glides should be e -glide; dir2, height 1/2: black screw and red rotation missing; dir3: black n -glide at height 1/2 and red n -glide missing; K: omit black n -glide in dir3
62.451	P_2nma	55.9.449	$P_{2c}b'am$	1434	a	c	$b/2$	
62.452	P_2nma	57.11.468	$P_{2a}bc'm$	1472	$c/2$	a	b	
62.453	P_2nma	63.13.523	$C_{pmm}m'$	1582	b	c	a	
62.454	P_2nma	63.14.524	$C_{pm'}c'm$	1584	c	a	b	
62.455	P_2nma	64.12.539	$C_{pmm}c'a$	1614	b	a	c	
62.456	P_2nma	74.11.660	$I_{pm'}ma'$	1858	a	b	c	
63.466	C_2mcm	65.12.556	$C_{2mm}m'm'$	1648	a	b	$c/2$	
63.467	C_2mcm	51.12.398	P_2mma	1330	c	$a/2$	$b/2$	L & K: omit black n -glide in dir3 L & K: omit red n -glide in dir3
63.468	C_2mcm	69.7.611	$F_{cm'}mm$	1759	b	a	c	
64.478	C_2mca	67.11.587	$C_{2m'}ma$	1710	b	a	$c/2$	
64.479	C_2mca	51.19.405	$P_2m'ma$	1345	c	$a/2$	$b/2$	K: some red inversion points marked incorrectly, omit red n -glide in dir3; L: dir1 black glide should be e -glide, omit red n -glide; dir2, height 1/2: black rotation and red screw missing; dir3: red n -glide at height 0 and black n -glide at height 1/2 missing
64.480	C_2mca	69.10.614	$F_{cmm}m'$	1765	a	b	c	
65.488	C_2mmm	65.8.552	$C_{2c}mmm$	1640	a	b	$c/2$	L & K: omit n -glides in dir3 K: omit black n -glide in dir3 L & K: omit n -glide in dir3; K: replace red glides in dir3 by an e -glide
65.489	C_2mmm	47.7.353	$P_{cm}mmm$	1234	$a/2$	$b/2$	c	
65.490	C_2mmm	69.6.610	$F_{cmm}m$	1757	a	b	c	
66.498	C_2ccm	65.11.555	$C_{2m'}m'm$	1646	a	b	$c/2$	L & K: omit n -glides in dir3 K: omit black n -glide in dir3; L, dir1, dir2: every other black axial glide should be an n -glide, the red glides are missing
66.499	C_2ccm	49.9.372	P_{ccm}	1278	$a/2$	$b/2$	c	
66.500	C_2ccm	69.9.613	$F_{cm'}m'm$	1763	a	b	c	L & K: omit black n -glides in dir3
67.508	C_2mma	67.8.584	$C_{2c}mma$	1704	a	b	$c/2$	K, dir1, dir2: red mirror and glide planes wrong K: omit red n -glide in dir3; L: axial glide in dir3 should be an e -glide
67.509	C_2mma	47.11.357	$P_{cmm}m'$	1246	$a/2$	$b/2$	c	
67.510	C_2mma	69.8.612	$F_{cmm}m'$	1761	a	b	c	L & K: omit red n -glide in dir3; K, dir1, dir2: red mirror and glide planes wrong
68.518	C_2cca	67.12.588	$C_{2m'}m'a$	1712	a	b	$c/2$	L & K: omit red n -glide in dir3 L & K: omit red n -glide in dir3
68.519	C_2cca	49.13.376	P_{ccm}'	1286	$a/2$	$b/2$	c	
68.520	C_2cca	69.11.615	$F_{cm'}m'm'$	1767	a	b	c	
69.526	F_2mmm	47.8.354	$P_{fmm}m$	1237	$a/2$	$b/2$	$c/2$	L: omit n -glides in dir1, dir2; rotations and screws in dir2 at height 1/2 have wrong colour; L & K: replace axial glides by e -glide in dir1, dir2
70.532	F_2ddd	48.6.363	$P_{fn}nn$	1259	$a/2$	$b/2$	$c/2$	
71.538	I_2mmm	65.10.554	$C_{pmm}m$	1644	a	b	$c/2$	
72.546	I_2bam	65.19.563	$C_{pm'}m'm$	1662	a	b	$c/2$	

Table 4 (continued)

Koptsik (1966)		Litvin (2008)-SM						Remarks [L = Litvin (2008)-SM, K = Koptsik (1966)]
BNS No.	BNS symbol	Litvin No.	OG symbol	Page	dir1	dir2	dir3	
72.547	I_{abam}	67.10.586	C_{pmma}	1708	c	b	$a/2$	L: dir2: rotations and screws have wrong colour; dir3: glide planes at height 1/2 have wrong colour
73.553	I_{cbca}	67.17.593	$C_{pn'ma'}$	1722	a	b	$c/2$	
74.561	I_{cmma}	67.16.592	$C_{pnm'a}$	1720	a	b	$c/2$	
74.562	I_{amma}	65.18.562	$C_{pn'mm}$	1660	c	b	$a/2$	

the BNS symbols have the great advantage that their centring symbol relates the BW2 types straightforwardly to the corresponding monochrome type. The interpretation being much more involved for the OG symbols than for the BNS symbols of the BW2 types, errors appear more likely: corrections to the original association of primes to OG symbols of BW2 types in Opechowski & Guccione (1965) were made by Opechowski (1986) and in the supplementary material to Litvin (2008). Moreover, in the supplementary materials to Litvin (2001, 2008) the definition of the OG symbols for the superfamilies 73 and 206 is based on ITC83, not, as intended, on ITC52.

In conclusion, it seems unfortunate that OG symbols were proposed as an alternative to the earlier-introduced BNS symbols, also because looking at a symbol of a BW2 type, one often does not know whether it is an OG or a BNS symbol. As an example, the BNS symbol $P_{Cmm}2$ corresponds to the OG symbol $C_{Pmm}2$ and the OG symbol $P_{Cmm}2$ corresponds to the BNS symbol $C_a mm2$.

To see how the supplementary material to Litvin (2008), which we shall refer to as Litvin (2008)-SM, can be used by those familiar with BNS notation, we have studied the diagrams of symmetry elements for orthorhombic Shubnikov space groups in Litvin's tables and compared them to those in Koptsik (1966). In the fourth edition of Volume A of *International Tables for Crystallography* (1995), which will be referred to as ITC95, a new graphical symbol was introduced for 'double' glide planes e , not parallel to the plane of projection. In Tables 2–5 it will be shown in the last column which diagrams in Koptsik (1966) and in Litvin (2008)-SM are affected by these new symbols. The last column of Tables 1–5 also gives corrections to the diagrams of both authors.

2. Shubnikov space groups related to point group 222

Table 1 lists the orthorhombic Shubnikov space-group types without mirror or glide planes. The first part of the BNS number gives the number of the BNS superfamily, the second part numerates the 562 orthorhombic Shubnikov space groups; the first part of the Litvin number gives the number of the OG superfamily, the middle part numerates the Shubnikov space groups within an OG superfamily, the last part numerates the 1651 Shubnikov space groups. The column 'Page' indicates the page in Litvin (2008)-SM on which the description of the Shubnikov space group starts. dir1, dir2 and dir3 refer to the directions downwards, to the right and towards the reader in the diagrams of symmetry elements (DSEs) given in

Litvin (2008)-SM. The conventional orthorhombic cell has lattice parameters a , b and c , respectively, in the first, second and third symmetry direction of the BNS symbol. An entry a , b or c in 'dir1' states that the downwards extension of the DSE in Litvin (2008)-SM corresponds to the lattice parameter a , b or c ; an entry $a/2$, $b/2$ or $c/2$ states that the downwards extension of the DSE in Litvin (2008)-SM corresponds to $a/2$, $b/2$ or $c/2$. The situation is analogous for 'dir2' and 'dir3'. If $c/2$ appears in 'dir3' then the height indications appearing in Litvin (2008)-SM are twice as big as those in Koptsik (1966); similarly $a/2$ or $b/2$ in 'dir3' mean that the height indications in Litvin (2008)-SM are expressed as fractions of $a/2$ or $b/2$, not of a or b .

The arrangement of Shubnikov space-group types within a BNS superfamily is always the same: First appears the monochrome type (M), then the grey type (G), then the BW1 types, and finally the BW2 types. Horizontal lines separate the BW2 types in Table 1 from the other types. Notice that for the M, G and BW1 types the BNS and OG symbols agree and we have dir1 = a , dir2 = b , dir3 = c . For this reason, the tables of orthorhombic groups related to $mm2$ and mmm will be split into two: one for the BW2 types and one for the remaining types.

Figure 1 Illustration of the remarks in Table 4 to the diagram of symmetry elements given by Litvin (2008)-SM for type 63.467 (Litvin number 51.12.398, OG symbol P_{4mma}). The symmetry elements in directions 2 and 3 missing in Litvin (2008)-SM have been added; the representation of the symmetry elements in direction 1 has been simplified, thus avoiding the necessity of splitting the diagram into two figures.

Table 5

The monochrome, grey and BW1 space-group types related to point group *mmm*.

BNS No.	Symbol	Litvin No.	Page	Notes
47.249	<i>Pmmm</i>	47.1.347	1216	
47.250	<i>Pmmm1'</i>	47.2.348	1219	
47.251	<i>Pm'mm</i>	47.3.349	1222	
47.252	<i>Pm'm'm</i>	47.4.350	1225	
47.253	<i>Pm'm'm'</i>	47.5.351	1228	
48.257	<i>Pnnn</i>	48.1.358	1249	
48.258	<i>Pnnn1'</i>	48.2.359	1251	
48.259	<i>Pn'nn</i>	48.3.360	1253	
48.260	<i>Pn'n'n</i>	48.4.361	1255	
48.261	<i>Pn'n'n'</i>	48.5.362	1257	
49.265	<i>Pccm</i>	49.1.364	1262	
49.266	<i>Pccm1'</i>	49.2.365	1264	
49.267	<i>Pc'cm</i>	49.3.366	1266	(1)
49.268	<i>Pccm'</i>	49.4.367	1268	(2)
49.269	<i>Pc'c'm</i>	49.5.368	1270	
49.270	<i>Pc'cm'</i>	49.6.369	1272	(3)
49.271	<i>Pc'c'm'</i>	49.7.360	1274	
50.277	<i>Pban</i>	50.1.377	1288	
50.278	<i>Pban1'</i>	50.2.378	1290	
50.279	<i>Pb'an</i>	50.3.379	1292	
50.280	<i>Pban'</i>	50.4.380	1294	
50.281	<i>Pb'a'n</i>	50.5.381	1296	
50.282	<i>Pb'an'</i>	50.6.382	1298	
50.283	<i>Pb'a'n'</i>	50.7.383	1300	
51.289	<i>Pmma</i>	51.1.387	1308	
51.290	<i>Pmma1'</i>	51.2.388	1310	
51.291	<i>Pm'ma</i>	51.3.389	1312	
51.292	<i>Pmm'a</i>	51.4.390	1314	
51.293	<i>Pmma'</i>	51.5.391	1316	
51.294	<i>Pm'm'a</i>	51.6.392	1318	
51.295	<i>Pmm'a'</i>	51.7.393	1320	(4)
51.296	<i>Pm'ma'</i>	51.8.394	1322	
51.297	<i>Pm'm'a'</i>	51.9.395	1324	
52.305	<i>Pnna</i>	52.1.406	1348	
52.306	<i>Pnna1'</i>	52.2.407	1350	
52.307	<i>Pn'na</i>	52.3.408	1352	(5)
52.308	<i>Pnn'a</i>	52.4.409	1354	(5)
52.309	<i>Pnna'</i>	52.5.410	1356	(5)
52.310	<i>Pn'n'a</i>	52.6.411	1358	(5)
52.311	<i>Pnn'a'</i>	52.7.412	1360	(5), (6)
52.312	<i>Pn'na'</i>	52.8.413	1362	(5), (7)
52.313	<i>Pn'n'a'</i>	52.9.414	1364	(5)
53.321	<i>Pmna</i>	53.1.415	1366	
53.322	<i>Pmna1'</i>	53.2.416	1368	
53.323	<i>Pm'na</i>	53.3.417	1370	
53.324	<i>Pmn'a</i>	53.4.418	1372	
53.325	<i>Pmna'</i>	53.5.419	1374	
53.326	<i>Pm'n'a</i>	53.6.420	1376	
53.327	<i>Pmn'a'</i>	53.7.421	1378	
53.328	<i>Pm'na'</i>	53.8.422	1380	
53.329	<i>Pm'n'a'</i>	53.9.423	1382	
54.337	<i>Pcca</i>	54.1.428	1392	
54.338	<i>Pcca1'</i>	54.2.429	1394	
54.339	<i>Pc'ca</i>	54.3.430	1396	
54.340	<i>Pcc'a</i>	54.4.431	1398	
54.341	<i>Pcca'</i>	54.5.432	1400	
54.342	<i>Pc'c'a</i>	54.6.433	1402	
54.343	<i>Pcc'a'</i>	54.7.434	1404	
54.344	<i>Pc'ca'</i>	54.8.435	1406	
54.345	<i>Pc'c'a'</i>	54.9.436	1408	
55.353	<i>Pbam</i>	55.1.441	1418	
55.354	<i>Pbam1'</i>	55.2.442	1420	

Table 5 (continued)

BNS No.	Symbol	Litvin No.	Page	Notes
55.355	<i>Pb'am</i>	55.3.443	1422	
55.356	<i>Pbam'</i>	55.4.444	1424	
55.357	<i>Pb'a'm</i>	55.5.445	1426	
55.358	<i>Pb'am'</i>	55.6.446	1428	
55.359	<i>Pb'a'm'</i>	55.7.447	1430	
56.365	<i>Pccn</i>	56.1.451	1438	
56.366	<i>Pccn1'</i>	56.2.452	1440	
56.367	<i>Pc'cn</i>	56.3.453	1442	
56.368	<i>Pccn'</i>	56.4.454	1444	
56.369	<i>Pc'c'n</i>	56.5.455	1446	
56.370	<i>Pc'cn'</i>	56.6.456	1448	
56.371	<i>Pc'c'n'</i>	56.7.457	1450	
57.377	<i>Pbcm</i>	57.1.458	1452	
57.378	<i>Pbcm1'</i>	57.2.459	1454	
57.379	<i>Pb'cm</i>	57.3.460	1456	
57.380	<i>Pbc'm</i>	57.4.461	1458	
57.381	<i>Pbcm'</i>	57.5.462	1460	
57.382	<i>Pb'c'm</i>	57.6.463	1462	
57.383	<i>Pbc'm'</i>	57.7.464	1464	
57.384	<i>Pb'cm'</i>	57.8.465	1466	
57.385	<i>Pb'c'm'</i>	57.9.466	1468	(8)
58.393	<i>Pnnm</i>	58.1.471	1478	
58.394	<i>Pnnm1'</i>	58.2.472	1480	
58.395	<i>Pn'nm</i>	58.3.473	1482	
58.396	<i>Pnnm'</i>	58.4.474	1484	
58.397	<i>Pn'n'm</i>	58.5.475	1486	
58.398	<i>Pnn'm'</i>	58.6.476	1488	
58.399	<i>Pn'n'm'</i>	58.7.477	1490	
59.405	<i>Pmmn</i>	59.1.478	1492	
59.406	<i>Pmmn1'</i>	59.2.479	1494	
59.407	<i>Pm'mn</i>	59.3.480	1496	
59.408	<i>Pmmn'</i>	59.4.481	1498	
59.409	<i>Pm'm'n</i>	59.5.482	1500	
59.410	<i>Pmm'n'</i>	59.6.483	1502	
59.411	<i>Pm'm'n'</i>	59.7.484	1504	
60.417	<i>Pbcn</i>	60.1.488	1512	
60.418	<i>Pbcn1'</i>	60.2.489	1514	
60.419	<i>Pb'cn</i>	60.3.490	1516	
60.420	<i>Pbc'n</i>	60.4.491	1518	(9)
60.421	<i>Pbcn'</i>	60.5.492	1520	
60.422	<i>Pb'c'n</i>	60.6.493	1522	
60.423	<i>Pbc'cn'</i>	60.7.494	1524	
60.424	<i>Pb'cn'</i>	60.8.495	1526	
60.425	<i>Pb'c'n'</i>	60.9.496	1528	
61.433	<i>Pbca</i>	61.1.497	1530	
61.434	<i>Pbca1'</i>	61.2.498	1532	
61.435	<i>Pb'ca</i>	61.3.499	1534	
61.436	<i>Pb'c'a</i>	61.4.500	1536	
61.437	<i>Pb'c'a'</i>	61.5.501	1538	
62.441	<i>Pnma</i>	62.1.502	1540	
62.442	<i>Pnma1'</i>	62.2.503	1542	
62.443	<i>Pn'ma</i>	62.3.504	1544	(10)
62.444	<i>Pnm'a</i>	62.4.505	1546	
62.445	<i>Pnma'</i>	62.5.506	1548	
62.446	<i>Pn'm'a</i>	62.6.507	1550	
62.447	<i>Pnm'a'</i>	62.7.508	1552	(11)
62.448	<i>Pn'ma'</i>	62.8.509	1554	
62.449	<i>Pn'm'a'</i>	62.9.510	1556	
63.457	<i>Cmcm</i>	63.1.511	1558	
63.458	<i>Cmcm1'</i>	63.2.512	1560	
63.459	<i>Cm'cm</i>	63.3.513	1562	(12)
63.460	<i>Cmc'm</i>	63.4.514	1564	(12)
63.461	<i>Cmcm'</i>	63.5.515	1566	(12)
63.462	<i>Cm'c'm</i>	63.6.516	1568	(12)

Table 5 (continued)

BNS No.	Symbol	Litvin No.	Page	Notes
63.463	<i>Cmc'm'</i>	63.7.517	1570	(12)
63.464	<i>Cm'cm'</i>	63.8.518	1572	(12)
63.465	<i>Cm'c'm'</i>	63.9.519	1574	(12)
64.469	<i>Cmca</i>	64.1.528	1592	
64.470	<i>Cmca1'</i>	64.2.529	1594	
64.471	<i>Cm'ca</i>	64.3.530	1596	
64.472	<i>Cmc'a</i>	64.4.531	1598	
64.473	<i>Cmca'</i>	64.5.532	1600	
64.474	<i>Cm'c'a</i>	64.6.533	1602	(13)
64.475	<i>Cmc'd'</i>	64.7.534	1604	
64.476	<i>Cm'ca'</i>	64.8.535	1606	
64.477	<i>Cm'c'a'</i>	64.9.536	1608	
65.481	<i>Cmmm</i>	65.1.545	1626	(14)
65.482	<i>Cmmm1'</i>	65.2.546	1628	(14)
65.483	<i>Cm'mm</i>	65.3.547	1630	(12)
65.484	<i>Cmmm'</i>	65.4.548	1632	(12)
65.485	<i>Cm'm'm</i>	65.5.549	1634	(12)
65.486	<i>Cmm'm'</i>	65.6.550	1636	(12)
65.487	<i>Cm'm'm'</i>	65.7.551	1638	(12), (15)
66.491	<i>Cccm</i>	66.1.564	1664	(14)
66.492	<i>Cccm1'</i>	66.2.565	1666	(14)
66.493	<i>Cc'cm</i>	66.3.566	1668	(12)
66.494	<i>Cccm'</i>	66.4.567	1670	(12)
66.495	<i>Cc'c'm</i>	66.5.568	1672	(12)
66.496	<i>Ccc'm'</i>	66.6.569	1674	(12)
66.497	<i>Cc'c'm'</i>	66.7.570	1676	(12)
67.501	<i>Cmma</i>	67.1.577	1690	
67.502	<i>Cmma1'</i>	67.2.678	1692	
67.503	<i>Cm'ma</i>	67.3.579	1694	(16)
67.504	<i>Cmma'</i>	67.4.580	1696	
67.505	<i>Cm'm'a</i>	67.5.581	1698	(17)
67.506	<i>Cmm'a'</i>	67.6.582	1700	
67.507	<i>Cm'm'a'</i>	67.7.583	1702	
68.511	<i>Ccca</i>	68.1.594	1724	
68.512	<i>Ccca1'</i>	68.2.595	1726	
68.513	<i>Cc'ca</i>	68.3.596	1728	
68.514	<i>Ccca'</i>	68.4.597	1730	
68.515	<i>Cc'c'a</i>	68.5.598	1732	
68.516	<i>Ccc'a'</i>	68.6.599	1734	(18)
68.517	<i>Cc'c'a'</i>	68.7.600	1736	
69.521	<i>Fmmm</i>	69.1.605	1746	(19), (20)
69.522	<i>Fmmm1'</i>	69.2.606	1748	(19), (20)
69.523	<i>Fm'mm</i>	69.3.607	1751	(19), (20)
69.524	<i>Fm'm'm</i>	69.4.608	1753	(19), (20)
69.525	<i>Fm'm'm'</i>	69.5.609	1755	
70.527	<i>Fddd</i>	70.1.616	1769	
70.528	<i>Fddd1'</i>	70.2.617	1771	
70.529	<i>Fd'dd</i>	70.3.618	1774	
70.530	<i>Fd'd'd</i>	70.4.619	1776	
70.531	<i>Fd'd'd'</i>	70.5.620	1778	
71.533	<i>Immm</i>	71.1.621	1780	
71.534	<i>Immm1'</i>	71.2.622	1782	
71.535	<i>Im'mm</i>	71.3.623	1784	
71.536	<i>Im'm'm</i>	71.4.624	1786	
71.537	<i>Im'm'm'</i>	71.5.625	1788	
72.539	<i>Ibam</i>	72.1.630	1798	
72.540	<i>Ibam1'</i>	72.2.631	1800	
72.541	<i>Ib'am</i>	72.3.632	1802	
72.542	<i>Ibam'</i>	72.4.633	1804	
72.543	<i>Ib'a'm</i>	72.5.634	1806	
72.544	<i>Iba'm'</i>	72.6.635	1808	
72.545	<i>Ib'a'm'</i>	72.7.636	1810	
73.548	<i>Ibca</i>	73.1.643	1824	

Table 5 (continued)

BNS No.	Symbol	Litvin No.	Page	Notes
73.549	<i>Ibca1'</i>	73.2.644	1826	
73.550	<i>Ib'ca</i>	73.3.645	1828	
73.551	<i>Ib'c'a</i>	73.4.646	1830	
73.552	<i>Ib'c'a'</i>	73.5.647	1832	
74.554	<i>Imma</i>	74.1.650	1838	
74.555	<i>Imma1'</i>	74.2.651	1840	
74.556	<i>Im'ma</i>	74.3.652	1842	
74.557	<i>Imma'</i>	74.4.653	1844	
74.558	<i>Im'm'a</i>	74.5.654	1846	
74.559	<i>Imm'a'</i>	74.6.655	1848	
74.560	<i>Im'm'a'</i>	74.7.656	1850	

Notes. (1) Koptsik (1966): glide planes in dir1 should be red; (2) Koptsik (1966): one glide plane in dir2 missing; (3) Koptsik (1966): there should be no black glide planes in dir1; (4) Koptsik (1966): one red arrow missing; (5) Koptsik (1966): there should be no mirror planes in dir2; (6) Litvin (2008)-SM: rotations in dir1 should be black, screws in dir2 should be red; (7) Litvin (2008)-SM: rotations in dir1 should be red, screws in dir2 should be black; (8) Litvin (2008)-SM, dir3: mirror plane should be red; (9) Koptsik (1966), dir3: red screws missing; (10) Litvin (2008)-SM, dir2: screws should be red; (11) Koptsik (1966), dir3: one screw axis missing; (12) Litvin (2008)-SM & Koptsik (1966): omit *n*-glide in dir3; (13) Litvin (2008)-SM: mirror and glide planes in dir1 should be red; (14) Litvin (2008)-SM: omit *n*-glide in dir3; (15) Koptsik (1966): inversion points should be red; (16) Litvin (2008)-SM: inversion points should be red; (17) Litvin (2008)-SM, dir2: mirror and glide planes should be red; (18) Koptsik (1966), dir2: some red glide planes missing; (19) Litvin (2008)-SM: omit *n*-glides in dir1, dir2 and dir3; (20) replace axial planes by *e*-glide in dir1 and dir2.

3. Shubnikov space groups related to point group *mm2*

Table 2 lists the orthorhombic BW2 space-group types with rotations or screws in one symmetry direction, and mirror or glide planes perpendicular to the two other symmetry directions. Horizontal lines separate types belonging to different BNS superfamilies.

Notice that if the centring part of the OG symbol is *P*_{2a}, *A*_{2a} or *A*₁, then a factor 1/2 appears in column 'dir1'; if the centring part of the OG symbol is *P*_{2b} then a factor 1/2 appears in 'dir2'; and if the centring part of the OG symbol is *P*_{2c}, *C*_{2c} or *C*₁, then a factor 1/2 appears in 'dir3'. If the centring part of the OG symbol is *P*_A, then a factor 1/2 appears in 'dir2' and 'dir3'; if the centring part of the OG symbol is *P*_C, then a factor 1/2 appears in 'dir1' and 'dir2'; and if the centring part of the OG symbol is *P*_F, then a factor 1/2 appears in 'dir1', 'dir2' and 'dir3'. Remember that a factor 1/2 in 'dir3' leads to doubling of the height values. These rules also hold for Tables 1 and 4.

The last column contains remarks and corrections to the DSEs in Litvin (2008)-SM and in Koptsik (1966). In both cases, dir1 tells us that a rotation or screw axis and the normal to a mirror or glide plane is vertical, dir2 tells us that it is horizontal, and dir3 tells us that it is perpendicular to the plane of the drawing.

The majority of remarks are connected with glide planes. A primed (unprimed) symmetry glide may be considered as a primed (unprimed) mirror reflection followed by an unprimed translation **t**. Whereas the combined operation belongs to the Shubnikov space group **S** under consideration, the mirror reflection alone and **t** alone are not elements of **S**. The glide vector **t** has the property that 2**t** is (and **t** is not) an unprimed symmetry translation. As an example for the orthorhombic lattice with conventional cell spanned by vectors **a**, **b** and **c**, we

consider a symmetry glide plane $\perp \mathbf{a}$. If the lattice is neither *A*- nor *F*-centred, then $\mathbf{t}$ will have the form $\mathbf{t} = \frac{1}{2}(h\mathbf{b} + k\mathbf{c})$, where h and k are integers that are not both even. The glide vector of a symmetry glide with a plane in a fixed orientation and position is determined only up to an unprimed (symmetry) translation. Therefore we may choose $\mathbf{t} = \mathbf{b}/2$ if h is odd and k is even, $\mathbf{t} = \mathbf{c}/2$ if h is even and k is odd, or $\mathbf{t} = \frac{1}{2}(\mathbf{b} + \mathbf{c})$ if h and k are odd. If the lattice is *A*- or *F*-centred, then $\frac{1}{2}(\mathbf{b} + \mathbf{c})$ is an unprimed (symmetry) translation, *i.e.* a mirror reflection followed by a translation $\frac{1}{2}(\mathbf{b} + \mathbf{c})$ becomes equivalent to the mirror reflection alone; a mirror reflection followed by a translation $\mathbf{b}/2$ becomes equivalent to the mirror reflection followed by a translation $\mathbf{c}/2$. The latter case is referred to as a ‘double glide’ or ‘*e*-glide’. The *e*-glides are denoted by a horizontal and a vertical arrow with common origin if the glide plane is parallel to the projection plane. If the glide plane is normal to the projection plane, they were denoted either as a dashed or dotted line in ITXC52 and in Koptsik (1966), as was usual before the introduction of the dash-dot-dot line in ITC95. The *e*-glides are denoted both by a dashed and a dotted line in Litvin (2008)-SM; the mirrors often both as mirror and as *n*-glide in Litvin (2008)-SM and Koptsik (1966). Representing equivalent symmetry elements by two symbols is both confusing and unnecessarily complicated, and it forced Litvin (2008)-SM to distribute the symmetry elements over two diagrams in some cases.

Table 3 lists the orthorhombic monochrome, grey and BW1 space-group types with rotations or screws in one symmetry direction, and mirror or glide planes perpendicular to the two other symmetry directions. Horizontal lines separate types belonging to different BNS superfamilies.

4. Orthorhombic Shubnikov space groups related to point group *mmm*

Table 4 lists the orthorhombic BW2 space-group types with mirror or glide planes perpendicular to all three symmetry directions. Horizontal lines separate types belonging to different BNS superfamilies.

The remarks in Table 4 to the diagram of symmetry elements given by Litvin (2008)-SM for 63.467 are illustrated in Fig. 1.

Table 5 lists the orthorhombic monochrome, grey and BW1 space-group types with mirror or glide planes perpendicular to all three symmetry directions. Horizontal lines separate types belonging to different BNS superfamilies.

5. Conclusions

Comparison of the diagrams of symmetry elements (DSEs) for the orthorhombic point groups given in Koptsik (1966) and in Litvin (2008)-SM showed the following main results.

In Koptsik (1966) some of the symmetry elements that differ only by a shift are missing in several cases. Lines deli-

miting the projection of the conventional cell appear as mirror planes in several cases. Mirror planes parallel to the plane of the diagram also appear sometimes as *n*-glides in the case of *C*-centred cells. In particular, in the case of vertical lines, it is sometimes not clear whether they denote mirrors, axial or diagonal glides.

In Litvin (2008)-SM *e*-glides are treated as two independent axial glides, which is misleading and unnecessarily complicates the DSEs. Mirror planes also sometimes appear as *n*-glides in the case of *C*- and *A*-centred cells.

Notice that if the lattice part of the OG symbol is P_F (P_A or P_C) then only $\frac{1}{4}$ ($\frac{1}{2}$) of the symmetry operations are listed under the heading ‘Symmetry Operations’ in Litvin (2008)-SM.

The standard symbols for BW2-type space groups proposed by Opechowski & Guccione (1965) and by Belov *et al.* (1957*a,b*), respectively, often correspond to different orientations of the space group, as shown in columns *dir1*, *dir2* and *dir3* of Tables 1, 2 and 4.

Whereas Litvin (2001) needs 216 pages of supplementary material to describe the meaning of the OG symbols, the meaning of the BNS symbols is obvious, including those for the BW2 types. Therefore the BNS symbols should be recognized as standard.

The author is grateful to Professor D. B. Litvin for discussions which gave him a clearer understanding of the definition of the Opechowski–Guccione symbols for BW2-type space groups.

References

- Belov, N. V., Neronova, N. N. & Smirnova, T. S. (1957*a*). *Kristallografiya*, **2**, 315–325.
- Belov, N. V., Neronova, N. N. & Smirnova, T. S. (1957*b*). *Sov. Phys. Crystallogr.* **2**, 311–322.
- Borovik-Romanov, A. S. & Grimmer, H. (2003). *International Tables for Crystallography*, Vol. D, edited by A. Authier, pp. 105–149. Dordrecht: Kluwer Academic Publishers.
- International Tables for Crystallography* (1983). Vol. A, *Space-Group Symmetry*, 1st ed., edited by Th. Hahn. Dordrecht: Reidel Publishing Company.
- International Tables for Crystallography* (1995). Vol. A, *Space-Group Symmetry*, 4th ed., edited by Th. Hahn. Dordrecht: Kluwer Academic Publishers.
- International Tables for X-ray Crystallography* (1952). Vol. I, *Symmetry Groups*, edited by N. F. M. Henry & K. Lonsdale. Birmingham: Kynoch Press.
- Koptsik, V. A. (1966). *Shubnikov Groups*. Moscow: Izd. M. U.
- Litvin, D. B. (1998). *Acta Cryst.* **A54**, 257–261.
- Litvin, D. B. (2001). *Acta Cryst.* **A57**, 729–730.
- Litvin, D. B. (2008). *Acta Cryst.* **A64**, 419–424.
- Opechowski, W. (1986). *Crystallographic and Metacrystallographic Groups*. Amsterdam: North-Holland.
- Opechowski, W. & Guccione, R. (1965). *Magnetism*, edited by G. T. Rado & H. Suhl, Vol. II, Part A, pp. 105–165. New York, London: Academic Press.