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Ferromagnetic Groups

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All magnetic structures can be described (in more or less complicated manner) with the aid of 1651 Shubnikov groups.

The number of (crystallographic) ferromagnetic space groups is restricted to 275, which are subgroups of the highest symmetry for the axial vector, $\infty/m\ 2'/m'\ 2'/m'$. This small proportion is due to the fact that most Shubnikov groups have got, as a symbol, one of the 230 before which the symbol of Bravais' lattice with black and white centering is placed, while in ferromagnetic groups only ordinary (one colour) lattices are possible. In ferromagnetic groups the ordinary equatorial plane of symmetry and meridional planes of antisymmetry are permitted, while the centre of antisymmetry is forbidden.

The symmetry of a normal magnetic structure acconnts not only for the positions of atoms in the unit cell, but also gives characteristics of the directions of magnetic moments (for magnetic atoms) and their magnitudes. This symmetry cannot be higher than the symmetry of the corresponding chemical structure, because in deriving the magnetic group from the generating Shoenflies-Fedorov group we either change a part or all elements of symmetry for the elements of antisymmetry or let them fall out.

Considering for instance a ferromagnetic structure with the space group $Im3m$ we have to anticipate magnetic moments oriented in one of four ways:

1. along the axis 4 [100].
2. along the axis $\bar{3}$ [111].
3. along the axis 2 [110].
4. along the arbitrary direction.

In every of these variants we have a limited but sometimes sufficiently large number for the selection of geometrically permitted possibilities which can be substantially curtailed when we utilize supplementary (physical, chemical) evidence about the substance.

Table I.

Crystallographic systems	No.	Ferromagnetic groups	
		Space	Point
Triclinic	1	$P1$	1
	2	$P\bar{1}$	$\bar{1}$
Monoclinic	3–5	$P121$, $P12_11$, $C121$	121
	6–8	$P112'$, $P112_1'$, $B112'$	$112'$
	9–12	$P1m1$, $P1c1$, $C1m1$, $C1c1$	$1m1$
	13–16	$P11m'$, $P11b'$, $B11m'$, $B11b'$	$11m'$
	17–22	$P12/m1$, $P12_1/m1$, $C12/m1$, $P12/c1$, $P12_1/c1$, $C12/c1$	$12/m1$
	23–28	$P112'/m'$, $P112_1'/m'$, $B112'/m'$, $P112'/c'$, $P112_1'/c'$, $B112'/c'$	$112'/m'$
Orthorhombic	29–41	$P2'2'2$, $P2'2'2_1$, $P2_1'2'2$, $P2_1'2_1'2$, $P2'2_1'2_1$, $P2_1'2_1'2_1$, $C2'2'2_1$, $A2_1'2'2$, $C2'2'2$, $A2'2'2$, $F2'2'2$, $I2'2'2$, $I2_1'2_1'2_1$	$2'2'2$
	42–63	$Pm'm'2$, $Pm'c'2_1$, $Pc'c'2$, $Pm'a'2$, $Pc'a'2_1$, $Pn'c'2$, $Pm'n'2_1$, $Pb'a'2$, $Pn'a'2_1$, $Pn'n'2$, $Cm'm'2$, $Cm'c'2_1$, $Cc'c'2$, $Am'm'2$, $Ab'm'2$, $Am'a'2$, $Ab'a'2$, $Fm'm'2$, $Fd'd'2$, $Im'm'2$, $Ib'a'2$, $Im'a'2$	$m'm'2$

Table I. (continued)

Crystallographic systems	No.	Ferromagnetic groups	
		Space	Point
Orthorhombic	64–97	$P2'm'm$, $P2_1'm'a$, $P2_1'a'm$, $P2_1'a'a$, $P2'c'm$, $P2'm'b$, $P2_1'c'a$, $P2_1'a'b$, $P2'a'n$, $P2'n'a$, $P2_1'n'm$, $P2_1'm'n$, $P2_1'c'b$, $P2_1'c'n$, $P2_1'n'b$, $P2'n'n$, $A2'm'm$, $A2_1'm'a$, $A2_1'a'm$, $A2'a'a$, $C2'm'm$, $B2'm'm$, $C2'm'b$, $B2'c'm$, $C2'c'm$, $B2'm'b$, $C2'c'b$, $B2'c'b$, $F2'm'm$, $F2'd'd$, $I2'm'm$, $I2'c'b$, $I2'm'b$, $I2'c'm$	$2'm'm$
	98–155	$Pm'm'm$, $Pn'n'n$, $Pc'c'm$, $Pm'a'a$, $Pb'a'n$, $Pn'c'b$, $Pm'm'a$, $Pb'm'm$, $Pm'c'm$, $Pn'n'a$, $Pb'n'n$, $Pn'c'n$, $Pm'n'a$, $Pb'm'n$, $Pn'c'm$, $Pc'c'a$, $Pb'a'a$, $Pb'c'b$, $Pb'a'm$, $Pm'c'b$, $Pc'c'n$, $Pn'a'a$, $Pb'c'm$, $Pm'c'a$, $Pb'm'a$, $Pn'n'm$, $Pm'n'n$, $Pm'm'n$, $Pn'm'm$, $Pb'c'n$, $Pn'c'a$, $Pb'n'a$, $Pb'c'a$, $Pn'm'a$, $Pb'n'm$, $Pm'c'n$, $Cm'c'm$, $Bb'm'm$, $Am'm'a$, $Cm'c'a$, $Bb'c'm$, $Pb'm'a$, $Cm'm'm$, $Am'm'm$, $Cc'c'm$, $Am'a'a$, $Cm'm'a$, $Ac'm'm$, $Cc'c'a$, $Ac'a'a$, $Fm'm'm$, $Fd'd'd$, $Im'm'm$, $Ib'a'm$, $Im'c'b$, $Ib'c'a$, $Im'm'a$, $Ic'm'm$	$m'm'm$
Tetragonal	155–161	$P4$, $P4_1$, $P4_2$, $P4_3$. $I4$, $I4_1$	4
	162–171	$P42'2'$, $P42_1'2'$, $P4_12'2'$, $P4_12_1'2'$, $P4_22'2'$, $P4_22_1'2'$, $P4_32'2'$, $P4_32_1'2'$, $I42'2'$, $I4_12'2'$	$42'2'$
	172–177	$P4/m$, $P4_2/m$, $P4/n$, $P4_2/n$, $I4/m$, $I4_1/a$	$4/m$
	178–189	$P4m'm'$, $P4b'm'$, $P4_2c'm'$, $P4_2n'm'$, $P4c'c'$, $P4n'c'$, $P4_2m'c'$, $P4_2b'c'$, $I4m'm'$, $I4c'm'$, $I4_1m'd'$, $I4_1c'd'$	$4m'm'$
	190–209	$P4/mm'm'$, $P4/mc'c'$, $P4/nb'm'$, $P4/nn'c'$, $P4/mb'm'$, $P4/mn'c'$, $P4/nm'm'$, $P4/nc'c'$, $P4_2/mm'c'$, $P4_2/mc'm'$, $P4_2/nb'c'$, $P4_2/nn'm'$, $P4_2/mb'c'$, $P4_2/mn'm'$, $P4_2/nm'c'$, $P4_2/nc'm'$, $I4/mm'm'$, $I4/mc'm'$, $I4_1/am'd'$, $I4_1/ac'd'$	$4/mm'm'$
	210–211	$P\bar{4}$, $I\bar{4}$	$\bar{4}$
	212–223	$P\bar{4}2'm'$, $P\bar{4}2'c'$, $P\bar{4}2_1'm'$, $P\bar{4}2_1'c'$, $P\bar{4}m'2'$, $P\bar{4}c'2'$, $P\bar{4}b'2'$, $P\bar{4}n'2'$, $I\bar{4}m'2'$, $I\bar{4}c'2'$, $I\bar{4}2'm'$, $I\bar{4}2'd'$	$\bar{4}2'm'$
Hexagonal	224–227	$P3$, $P3_1$, $P3_2$, $R3$	3
	228–234	$P312'$, $P32'1$, $P3_112'$, $P3_12'1$, $P3_212'$, $P3_22'1$, $R32$	$32'$
	235–240	$P3m'1$, $P31m'$, $P3c'1$, $P31c'$, $R3m$, $R3c$	$3m'$
	241–242	$P\bar{3}$, $R\bar{3}$	$\bar{3}$
	243–248	$P\bar{3}1m'$, $P\bar{3}1c'$, $P\bar{3}m'1$, $P\bar{3}c'1$, $R\bar{3}m'$, $R\bar{3}c'$	$\bar{3}m'$
	249–254	$P6$, $P6_1$, $P6_5$, $P6_2$, $P6_4$, $P6_3$	6
	255–260	$P62'2'$, $P6_12'2'$, $P6_52'2'$, $P6_22'2'$, $P6_42'2'$, $P6_32'2'$	$62'2'$
Hexagonal	261	$P\bar{6}$	$\bar{6}$
	262–265	$P\bar{6}m'2'$, $P\bar{6}c'2'$, $P\bar{6}2'm'$, $P\bar{6}2'c'$	$\bar{6}m'2'$
	266–267	$P6/m$, $P6_3/m$	$6/m$
	268–271	$P6m'm'$, $P6c'c'$, $P6_3c'm'$, $P6_3m'c'$	$6m'm'$
	272–275	$P6/mm'm'$, $P6/mc'c'$, $P6_3/mc'm'$, $P6_3/mm'c'$	$6/mm'm'$