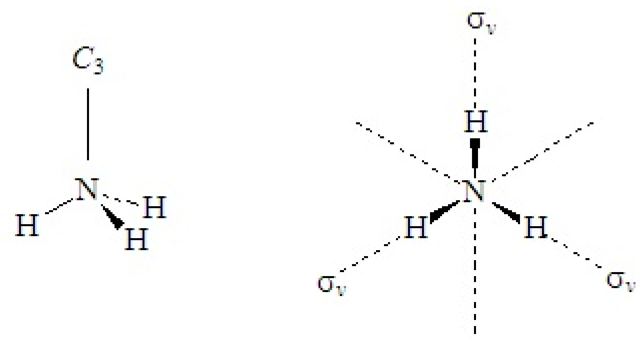
Chapter 1
Answers to Problems

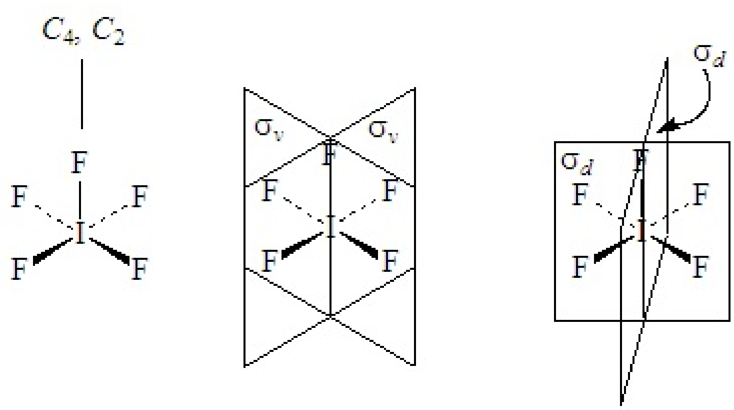
1.1 Only elements and operations other than identity (E) are shown.

(a) NH_3 (C_{3v})



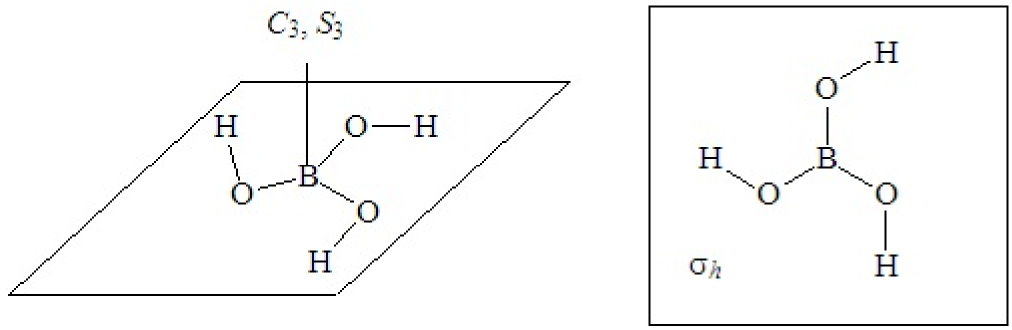
Elements	Operations
C_3	C_3, C_3^2
$3\sigma_v$	$3\sigma_v$

(b) IF_5 (C_{4v})



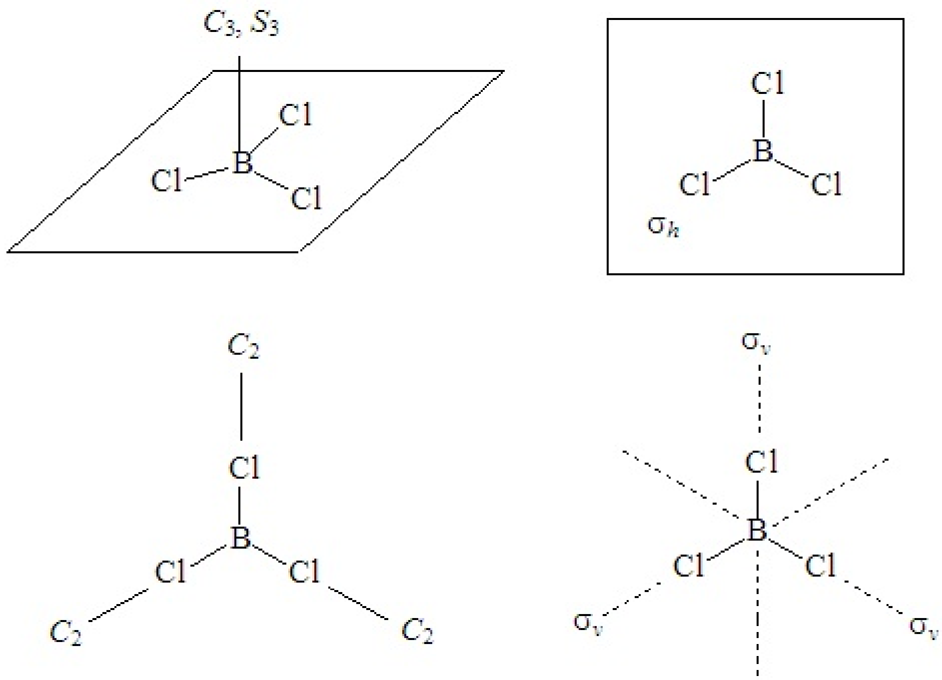
Elements	Operations
C_4, C_2	C_4, C_2, C_4^3
$2\sigma_v$	$2\sigma_v$
$2\sigma_d$	$2\sigma_d$

(c) $B(OH)_3$ (C_{3h})



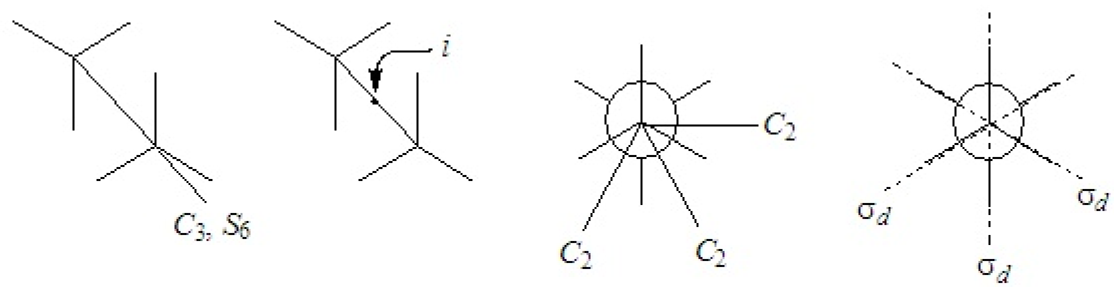
Elements	Operations
C_3	C_3, C_3^2
σ_h	σ_h
S_3	S_3, S_3^5

(d) BCl_3 (D_{3h})



Elements	Operations
C_3	C_3, C_3^2
$3C_2$	$3C_2$
σ_h	σ_h
S_3	S_3, S_3^5
$3\sigma_v$	$3\sigma_v$

(e) C_2H_6 (staggered configuration) (D_{3d})



Elements	Operations
C_3	C_3, C_3^2
$3C_2$	$3C_2$
i	i
S_6	S_6, S_6^5
$3\sigma_d$	3σ

1.2 The presence of C_4 implies the series of operations C_4, $C_4^2 = C_2$, C_4^3. Taking these with σ_h gives the following products: $C_4\sigma_h = \sigma_h C_4 = S_4$; $C_2\sigma_h = \sigma_h C_2 = i$; $C_4^3\sigma_h = \sigma_h C_4^3 = S_4^3$. Including E, the closed set includes eight operations, which become the eight elements of the group C_{4h}.

1.3 The group order of C_{4h} is $h = 8$. Therefore, the possible group orders are $g = 4, 2, 1$. For $g = 4$, we have the set $\{E, C_4, C_2, C_4^3\}$, which is the cyclic group C_4, and the set $\{E, S_4, C_2, S_4^3\}$, which is the cyclic group S_4. We also have the set $\{E, C_2, i, \sigma_h\}$, which is the non-cyclic group C_{2h}. For $g = 2$, we have the following closed sets: $\{E, C_2\} = C_2$; $\{E, \sigma_h\} = C_s$, $\{E, i\} = C_i$. Including the trivial group C_1, these are all the possible subgroups.

1.4 Note: All cyclic groups are Abelian.

(a) $C_3 = \{E, C_3, C_3^2\}$ Its multiplication table is

C_3	E	C_3	C_3^2
E	E	C_3	C_3^2
C_3	C_3	C_3^2	E
C_3^2	C_3^2	E	C_3

Subgroup: C_1

(b) $C_6 = \{E, C_6, C_3, C_2, C_3^2, C_6^5\}$ Its multiplication table is

C_6	E	C_6	C_3	C_2	C_3^2	C_6^5
E	E	C_6	C_3	C_2	C_3^2	C_6^5
C_6	C_6	C_3	C_2	C_3^2	C_6^5	E
C_3	C_3	C_2	C_3^2	C_6^5	E	C_6
C_2	C_2	C_3^2	C_6^5	E	C_6	C_3
C_3^2	C_3^2	C_6^5	E	C_6	C_3	C_2
C_6^5	C_6^5	E	C_6	C_3	C_2	C_3^2

Subgroups: C_3, C_2, C_1

(c) $S_4 = \{E, S_4, C_2, S_4^3\}$ Its multiplication table is

S_4	E	S_4	C_2	S_4^3
E	E	S_4	C_2	S_4^3
S_4	S_4	C_2	S_4^3	E
C_2	C_2	S_4^3	E	S_4
S_4^3	S_4^3	E	S_4	C_2

Subgroups: C_2, C_1

1.5 The multiplication table is

C_{2h}	E	C_2	i	σ_h
E	E	C_2	i	σ_h
C_2	C_2	E	σ_h	i
i	i	σ_h	E	C_2
σ_h	σ_h	i	C_2	E

All binary combinations commute, so the group is Abelian. Note also that the diagonal of E's indicates that each operation is its own reciprocal.

1.6 (a) C_s (assuming the reverse is blank)
(b) C_{2h}
(c) C_{2v} (assuming an identical reverse)
(d) D_{6h}
(e) C_{6v}
(f) C_s
(g) C_{2v}
(h) D_{3h}
(i) D_{2h}
(j) $C_{\infty v}$
(k) C_s
(l) $D_{\infty h}$
(m) D_{2d} (Hold it so that the seam presents an S profile to see the two dihedral C_2 axes.)
(n) D_4
(o) I_h (like C_{60}).

1.7 (a) square pyramid, C_{4v}
(b) bent, C_{2v} [Text should have ClF_2^+, not CIF_2^+ as printed. "CIF_2^+" would also be C_{2v}.]
(c) irregular tetrahedron, C_{2v}
(d) centrosymmetric linear, $D_{\infty h}$
(e) square planar, D_{4h}
(f) trigonal planar, D_{3h}
(g) octahedral, O_h
(h) noncentrosymmetric linear, $C_{\infty v}$
(i) tetrahedral, T_d
(j) trigonal bipyramid with O axial, C_{3v}
(k) *trans* planar, C_{2h}
(l) *cis* planar, C_{2v}
(m) nonplanar, C_2
(n) tetrahedral with one unique S-S bond, C_{3v}
(o) octahedral with *trans* Xe-O bonds, D_{4h}

1.8 (a) $D_{3h} \rightarrow C_{3v}$ (b) $T_d \rightarrow D_{2d}$ (c) $D_{4h} \rightarrow D_{2h}$ (d) $D_{3h} \rightarrow D_{3h}$ (e) $D_{3h} \rightarrow C_{2v}$ (f) $D_{3h} \rightarrow C_s$
(g) $O_h \rightarrow D_{4h}$ (h) $O_h \rightarrow D_{3d}$

1.9 (a) D_3, chiral
(b) D_{2h}, nonchiral
(c) C_2, chiral
(d) C_{2v} (assuming the oxalate ring is essentially planar on average), nonchiral
(e) C_1, chiral

1.10 (a) D_{3h} (b) C_s (c) C_2 (d) C_3 (e) D_3 (f) C_2
(g) C_s (h) C_{3v} (i) D_{3d} (j) C_{2h} (k) C_i (l) C_s
(m) C_{2v} (n) C_s (o) D_{2d} (p) C_1 (q) T_d (r) C_{3v}
(s) C_s (t) C_3 (u) D_{2d} (v) S_4 (w) C_{2v} (x) D_{6h}
(y) D_{3d} (z) C_{2h}

1.11 (a) D_{5h} (b) C_2 (c) C_{2v} (d) C_{5v} (e) C_2 (f) C_s
(g) C_s (h) C_1 (i) C_1 (j) C_s (k) C_1 (l) C_s

1.12 (a) C_{2v} (b) C_{2v} (c) C_{2v} (d) D_{2h} (e) D_{3h} (f) D_{2d}
(g) C_s (h) D_{6h} (i) D_{2h} (j) D_{3h} (k) C_s (l) C_{2v}
(m) C_{2v} (n) C_s (o) C_s (p) C_{2v} (q) C_s (r) C_{2v}
(s) D_{3h} (t) C_1