4-1

a. Ethane in the staggered conformation has 2 $C_3$ axes (the C–C line), 3 perpendicular $C_2$ axes bisecting the C–C line, in the plane of the two C's and the H's on opposite sides of the two C's. No $\sigma_h$, 3 $\sigma_d$, $i$, $S_6$. Overall, a $D_{3d}$ molecule.

b. Ethane in eclipsed conformation has two $C_3$ axes (the C–C line), three perpendicular $C_2$ axes bisecting the C–C line, in the plane of the two C's and the H's on the same side of the two C's. Mirror planes include $\sigma_h$ and 3 $\sigma_d$. Overall, a $D_{3h}$ molecule.

c. Chloroethane in the staggered conformation has only one mirror plane, through both C's, the Cl, and the opposite H on the other C. Overall, a $C_s$ molecule.

d. 1,2-dichloroethane in the gauche conformation has a $C_2$ axis perpendicular to the C–C bond and splitting the angle between the two C–Cl bonds. Overall, a $C_2$ molecule. In the trans conformation, it has a $C_2$ axis perpendicular to the C–C bond and perpendicular to the plane of both Cl's and both C's, a $\sigma_h$ plane through both Cl's and both C's, and an inversion center. Overall, a $C_{2v}$ molecule.

4-2

a. Ethylene is a planar molecule, with $C_2$ axes through the C's, and perpendicular to the C–C bond both in the plane of the molecule and perpendicular to it. It also has a $\sigma_h$ plane and two $\sigma_d$ planes (arbitrarily assigned). Overall, a $D_{2h}$ molecule.

b. Chloroethylene is also a planar molecule, with the only symmetry element the mirror plane of the molecule. Therefore, a $C_s$ molecule.

c. 1,1-dichloroethylene has a $C_2$ axis coincident with the C–C bond, and two mirror planes, one the plane of the molecule and one perpendicular to the plane of the molecule through both C's. Overall, a $C_{2v}$ molecule.

cis-1,2-dichloroethylene has a $C_2$ axis perpendicular to the C–C bond and in the plane of the molecule, two mirror planes (one the plane of the molecule and one perpendicular to the plane of the molecule and perpendicular to the C–C bond). Overall, a $C_{2v}$ molecule.

trans-1,2-dichloroethylene has a $C_2$ axis perpendicular to the C–C bond and perpendicular to the plane of the molecule, a mirror plane in the plane of the molecule, and an inversion center. Overall, a $C_{2h}$ molecule.
1,1'-Dichloroferrocene has a $C_2$ axis parallel to the rings, through the Fe and perpendicular to the Cl–Fe–Cl $\sigma_h$ mirror plane. It also has an inversion center. Overall, $C_{2h}$.

Dibenzenechromium has collinear $C_6$, $C_3$, and $C_2$ axes perpendicular to the rings, six perpendicular $C_2$ axes, and a $\sigma_h$ plane, making it a $D_{6h}$ molecule. It also has three $\sigma_v$ and three $\sigma_d$ planes, $S_3$ and $S_6$ axes, and an inversion center.

Benzenediphencylchromium has a mirror plane through the Cr and the diphenyl bridge bond and no other symmetry elements, so it is a $C_s$ molecule.

$\text{H}_3\text{O}^+$ has the same symmetry as $\text{NH}_3$, a $C_3$ axis, and three $\sigma_v$ planes for a $C_{3v}$ molecule.

$\text{O}_2\text{F}_2$ has a $C_2$ axis perpendicular to the O–O bond and perpendicular to a line connecting the fluorines. With no other symmetry elements, it is a $C_2$ molecule.

Formaldehyde has a $C_2$ axis collinear with the C=O bond, a mirror plane including all the atoms and another perpendicular to the first and including the C and O atoms. Overall, $C_{2v}$.

$\text{S}_8$ has $C_4$ and $C_2$ axes perpendicular to the average plane of the ring, four $C_2$ axes through opposite bonds, and four mirror planes perpendicular to the ring, each including two S atoms. Overall, $D_{4d}$.

Borazine has a $C_3$ axis perpendicular to the plane of the ring, three perpendicular $C_2$ axes, and a horizontal mirror plane. Overall, $D_{3h}$.

Tris(oxalato)chromate(III) has a $C_3$ axis and three perpendicular $C_2$ axes, each splitting a C–C bond and passing through the Cr. Overall, $D_3$.

A tennis ball has three perpendicular $C_2$ axes (one through the narrow portions of each segment, the others through the seams) and two mirror planes including the first rotation axis. Overall, $D_{2d}$.
4-8  a. VOCl₃ has $C_{3v}$ symmetry.
    b. PCl₃ has $C_{3v}$ symmetry.
    c. SOF₄ has $C_{2v}$ symmetry
    d. ClO₂⁻ has $C_{2v}$ symmetry.
    e. ClO₅⁻ has $C_{3v}$ symmetry.
    f. P₄O₆ has $T_d$ symmetry.

b.  a. PH₃ has $C_{3v}$ symmetry.
    b. H₂Se has $C_{2v}$ symmetry.
    c. SeF₄ has $C_{2v}$ symmetry.
    d. PF₅ has $D_{3h}$ symmetry.
    e. ICl₄⁻ has $D_{4h}$ symmetry.
    f. XeO₃ has $C_{3v}$ symmetry.
    g. NO₅⁻ has $D_{3h}$ symmetry.
    h. SnCl₂ has $C_{2v}$ symmetry in the vapor phase.
    i. PO₄³⁻ has $T_d$ symmetry.
    j. SF₆ has $O_h$ symmetry.
    k. IF₅ has $C_{4v}$ symmetry.
    l. ICl₃ has $C_{2v}$ symmetry.
    m. S₂O₃²⁻ has $C_{3v}$ symmetry.
    n. BF₂Cl has $C_{2v}$ symmetry.

4-10  a. $p_z$ has $C_{nv}$ symmetry. Ignoring the difference in sign between the two lobes, it is $D_{2h}$.
    b. $d_{xy}$ has $D_{2h}$ symmetry. Ignoring the signs, it is $D_{4h}$.
    c. $d_{x^2-y^2}$ has $D_{2h}$ symmetry. Ignoring the signs, it is $D_{4h}$.
    d. $d_{z^2}$ has $D_{2h}$ symmetry.