Solutions to assigned questions

Note that the odd-numbered questions at the end of the chapters have answers in Appendix O of Kotz, Treichel and Weaver. Even numbered problem solutions are below.

10.2 There are 26 electrons, giving the Lewis structure for NF₃ as
\[
\begin{array}{c}
\text{F} \\
\text{N} \\
\text{F}
\end{array}
\]
The electron geometry is tetrahedral (3 BPs + 1 LP).
The molecular geometry is trigonal pyramidal, with bond angles of 109.5°. The nitrogen requires four hybrid molecular orbitals, so its hybridization is sp³. One of the nitrogen sp³ orbitals overlaps with a 2p orbital for each fluorine to make the sigma bond between the two atoms.

10.8. a) XeOF₄ The Lewis structure identifies Xe as the central atom; there are 8 + 6 + 4(7) = 42 valence electrons. Make the 5 sigma bonds, fill outer atoms and place the remaining 2 electrons in a LP on the Xe. The F and O atoms have octets, Xe does not. Notice that the formal charge on Xe is +1 and that on O is -1. To minimize the formal charges, move one of the O LPs to make a pi bond to the Xe. Now all atoms have formal charge of zero. This is the correct Lewis structure. There are six electron “lumps”, making the electron geometry octahedrall. One position is occupied by a LP, so the molecular geometry is square pyramidal.

\[
\begin{array}{c}
\text{F} \\
\text{Xe} \\
\text{O} \\
\text{F}
\end{array}
\]
The central Xe has five sigma bonds plus one lone pair, or a total of 6 hybrid orbitals. That would require 1 s, 3 ps and 2 ds, making the hybridization sp³d².

b) BrF₅ The Lewis structure identifies Br as the central atom (the least electronegative); there are 7 + 5(7) = 42 valence electrons. Make the 5 sigma bonds, fill outer atoms and place the remaining 2 electrons in a LP on the Br. The F atoms have octets, Br does not. Notice that the formal charge on all atoms is zero. This is the correct Lewis structure. There are six electron “lumps”, making the electron geometry trigonal bipyramidal. One position (in the trigonal plane) is occupied by a LP, so the molecular geometry is see-saw.

\[
\begin{array}{c}
\text{F} \\
\text{Br} \\
\text{F}
\end{array}
\]
The central Br has five sigma bonds plus one lone pair, or a total of 6 hybrid orbitals. That would require 1 s, 3 ps and 1 d, making the hybridization sp³d.

c) OSF₄ The Lewis structure identifies S as the central atom (the least electronegative); there are 6 + 6 + 4(7) = 40 valence electrons. Make the 4 sigma bonds and fill the outer atoms. The F atoms have octets as does the O. The central S has five bonds, so it exceeds an octet. The
formal charge on each F is zero. On O it is -1 and on S it is +1. We cannot make a double bond between S and O because there are no available 2p orbitals on S (they have been used in the hybridization). Since O is more electronegative than S, we want the negative charge on O and the positive charge on S. This is the correct Lewis structure. There are five electron “lumps” around S, making the electron geometry trigonal bipyramidal. All positions are occupied by F and O atoms, so the molecular geometry is also trigonal bipyramidal.

\[
\begin{array}{c}
\vdots \\
F \\
\vdots \\
S \\
\vdots \\
F \\
\vdots \\
O
\end{array}
\]

The central S has five sigma bonds and no lone pairs, or a total of 5 hybrid orbitals. That would require 1 s, 3 ps and 1 d orbital from S, making the hybridization sp³d.

d) \( \text{Br}_3^− \) One of the Br is the central atom; there are 3(7) + 1 = 22 valence electrons. Make the 2 sigma bonds and fill the outer atoms. That leaves 6 electrons, so put them on the central Br. The two outer Br have filled octets and zero formal charge. The central Br has one extra electron pair and a formal charge of -1. There is no way to improve the charge; this is as close to zero as we can get with this structure, so this is the correct Lewis structure. There are five electron “lumps”, making the electron geometry trigonal bipyramidal. Two positions are occupied by Br atoms with the three lone pairs in the trigonal plane, maximizing their separation at 120°, so the molecular geometry is linear.

\[
\begin{array}{c}
\vdots \\
\vdots \\
\vdots \\
\vdots \\
\vdots \\
\vdots \\
\vdots
\end{array}
\]

The central Br has two sigma bonds and 3 lone pairs, or a total of 5 hybrid orbitals. That would require 1 s, 3 ps, and 1 d atomic orbitals, making the hybridization sp³d.

10.30. a) Carbon 1 has three sigma bonds and no lone pairs, so it is sp² hybridized. Carbon 2, likewise, is sp² hybridized.

b) Around carbon 1 the three sp² orbitals are in a planar trigonal arrangement, thus the bond angle A is that for a planar trigonal geometry, or 120°. The same is true for the other two angels for the same reason.

c) No, there is only possible configuration of acrolein. You might think that rotation around the C=C double bond would put the –CHO group “up” instead of “down” as it’s drawn in the book, but notice that the far left-hand carbon has two identical H atoms, one “up” and one “down”. Thus, twisting the C=C double bond by 180° by “holding on” to the –CHCHO part of the molecule will produce the same –CH₂ on the left-hand side of acrolein. Both “ends” that are connected by a double bond must be asymmetric in order for cis and trans isomers to be possible, and that’s not the case here.

10.32. a) A: 120° because the central C has trigonal planar electronic geometry.

B: 109.5° because the central O has tetrahedral electronic geometry.

C: 109.5° because the central C has tetrahedral electronic geometry.
D: 120° because the central C has trigonal planar electronic geometry.

b) 1: sp² because the central C has trigonal planar electronic geometry.
2: sp² because the central C has trigonal planar electronic geometry.
3: sp³ because the central C has tetrahedral electronic geometry.

10.38. IO₄⁻ has 32 electrons. Putting I in the center (it is less electronegative than O) and making the four sigma bonds leaves 24 electrons. Put 6 LP electrons around each O. That takes care of all of them, and all atoms have octets, so that is the correct Lewis structure. There are four sets of sigma BP electrons around the iodine, so the electron geometry is tetrahedral. So is the molecular geometry since three are no LP electrons on the iodine. The hybridization of I is sp³ as four molecular orbitals are used.

IO₅³⁻ has 40 electrons. I must be in the center. Put five sigma bonds to the five oxygens. Then put 6 LP electrons on each O. That totals 40 electrons. There are thus five sigma BPs around the iodine, so the molecular and electronic geometries are both trigonal bipyramidal. The five sigma BPs require five hybrid orbitals, so the hybridization must be sp³d.