**Homework #6**

# *Chapter 13*

*Bonding: General Concepts*

17. Electronegativity increases from left to right across periods and from low to high along groups.

| | | | | | |
|---|---|---|---|---|---|
| a) | C<N<O | b) | Se<S<Cl | c) | Sn<Ge< Si |
| d) | Tl<Ge<S | e) | Rb<K<Na | f) | Ga<B<O |

18. The most polar bond will be the bond that will be between elements that have the greatest difference in electronegativity.

| | | | | | |
|---|---|---|---|---|---|
| a) | Ge-F | b) | P-Cl | c) | S-F |
| d) | Ti-Cl | e) | Sn-H | f) | Tl-Br |

22. The greater the difference in electronegativity the more polar the bond

    F-H>O-H>N-H>C-H>P-H

23. The more polar the bonds the more ionic character the bond has.

    Br-Br<N-O<C-F<Ca-O<K-F

27. When an element forms an anion (- charged ion) it gains an electron. Since there are more electrons, there is more electron-electron repulsion. In addition, the number of protons does not change, causing the protons to have a greater negative charge to contain, resulting in a larger atomic radius.

    When an element forms a cation (+ charged ion) it loses an electron. Since there are fewer electrons, there is less electron-electron repulsion. In addition, the number of protons does not change, causing the protons to have a smaller negative charge to contain, resulting in a smaller atomic radius.

    Isoelectronic: Ions containing the same number of electrons.

    In isoelectronic ions the ion with the largest atomic number (Z) will have the smallest radius because the ion with the largest Z will have the most protons. The ion with the smallest atomic number (Z) will have the largest radius.

28.

| | | | | | |
|---|---|---|---|---|---|
| $Sc^{3+}$ | p=21 $e^-$=18 | $Cl^-$ | p=17 $e^-$=18 | $K^+$ | p=19 $e^-$=18 |
| $Ca^{2+}$ | p=20 $e^-$=18 | $S^{2-}$ | p=16 $e^-$=18 | | |

From smallest to largest

$Sc^{3+}<Ca^{2+}< K^+< Cl^-<S^{2-}$

Therefore in the order of the picture $K^+$, $Ca^{2+}$, $Sc^{3+}$, $S^{2-}$, and $Cl^-$

29.

| | | | | | |
|---|---|---|---|---|---|
| a) | $Cu> Cu^+>Cu^{2+}$ | b) | $Pt^{2+}>Pd^{2+}>Ni^{2+}$ | c) | $O^{2-}>O^->O$ |
| d)* | $Eu^{3+}>Gd^{3+}> Yb^{3+>} >La^{3+}$ | e) | $Te^{2-}>I^->Cs^+>Ba^{2+}>La^{3+}$ | | |

* $La^{3+}$ is the smallest ion because it loses its entire 6s and 4d shells

30. a) $Mg^{2+}=1s^22s^22p^6$
$Sn^{2+}=[Kr]5s^24d^{10}$
$K^+=1s^22s^22p^63s^23p^6$
$Al^{3+}=1s^22s^22p^6$
$Tl^+=[Xe]6s^24f^{14}5d^{10}$
$As^{3+}=[Ar]4s^23d^{10}$

b) $N^{3-}=1s^22s^22p^6$
$O^{2-}=1s^22s^22p^6$
$F^-=1s^22s^22p^6$
$Te^{2-}=[Kr]5s^24d^{10}5p^6$

31. $Rb^+=[Ar]4s^23d^{10}4p^6$ $Ba^{2+}=[Kr]5s^24d^{10}5p^6$ $Se^{2-}=[Ar]4s^23d^{10}4p^6$
$I^-=[Kr]5s^24d^{10}5p^6$

32. a) NaF b) CaS c) RbBr d) BaTe

33. a) $Cs^+=[Xe]$, $S^{2-}=[Ar]$ b) $Sr^{2+}=[Kr]$, $F^-=[Ne]$ c) $Ca^{2+}=[Ar]$, $N^{3-}=[Ne]$ d) $Al^{3+}=[Ne]$, $Br^-=[Kr]$

34. a) $Sc^{3+}$ b) $Te^{2-}$ c) $Ti^{4+}$ and $Ce^{4+}$ d) $Ba^{2+}$

37. a) $Al_2S_3$ aluminum sulfide b) $K_3N$ potassium nitride
c) $MgCl_2$ magnesium chloride d) CsBr cesium bromide

47. $\Delta H - \sum D(bonds\ broken) - \sum D(bonds\ formed)$

a) $\Delta H = D_{H-H} + D_{Cl-Cl} - 2D_{H-Cl}$
$\Delta H = 432\,\frac{kJ}{mol} + 239\,\frac{kJ}{mol} - 2\left(427\,\frac{kJ}{mol}\right) = -183\,\frac{kJ}{mol}$

b) $\Delta H = D_{N\equiv N} + 3D_{H-H} - 6D_{N-H}$
$\Delta H = 941\,\frac{kJ}{mol} + 3\left(432\,\frac{kJ}{mol}\right) - 6\left(391\,\frac{kJ}{mol}\right) = -109\,\frac{kJ}{mol}$

c) $\Delta H = D_{C\equiv N} + 2D_{H-H} - 2D_{C-H} - D_{C-N} - 2D_{N-H}$
$\Delta H = 891\,\frac{kJ}{mol} + 2\left(432\,\frac{kJ}{mol}\right) - 2\left(413\,\frac{kJ}{mol}\right) - 305\,\frac{kJ}{mol} - 2\left(391\,\frac{kJ}{mol}\right) = -158\,\frac{kJ}{mol}$

d) $\Delta H = 4D_{N-H} + 2D_{N-N} - 2D_{F-F} - D_{N\equiv N} - 4D_{H-F}$
$\Delta H = 4\left(391\,\frac{kJ}{mol}\right) + 160\,\frac{kJ}{mol} + 2\left(154\,\frac{kJ}{mol}\right) - 941\,\frac{kJ}{mol} - 4\left(565\,\frac{kJ}{mol}\right) = -1169\,\frac{kJ}{mol}$

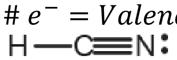
49. $\Delta H - \sum D(bonds\ broken) - \sum D(bonds\ formed)$
$\Delta H = D_{C-N} - D_{C-C}$
$\Delta H = 305\,\frac{kJ}{mol} - 347\,\frac{kJ}{mol} = -42\,\frac{kJ}{mol}$

52. $\Delta H - \sum D(bonds\ broken) - \sum D(bonds\ formed)$
$\Delta H = 4D_{C-H} + 2D_{O=O} - 2D_{C=O} - 4D_{H-O}$
$\Delta H = 4\left(413\,\frac{kJ}{mol}\right) + 2\left(495\,\frac{kJ}{mol}\right) - 2\left(799\,\frac{kJ}{mol}\right) - 4\left(467\,\frac{kJ}{mol}\right) = -824\,\frac{kJ}{mol}$

63. a)

| HCN | H | C | N | Total |
|---|---|---|---|---|
| Valence $e^-$ | 1 | 4 | 5 | 10 |
| Wanted $e^-$ | 2 | 8 | 8 | 18 |

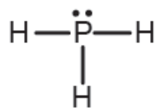
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{18 - 10}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 10 - 2(4) = 2$$



b)

| $PH_3$ | P | 3(H) | Total |
|---|---|---|---|
| Valence $e^-$ | 5 | 3(1) | 8 |
| Wanted $e^-$ | 8 | 3(2) | 14 |

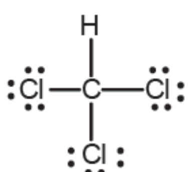
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{14 - 8}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 8 - 2(3) = 2$$



c)

| $CHCl_3$ | C | H | 3(Cl) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 4 | 1 | 3(7) | 26 |
| Wanted $e^-$ | 8 | 2 | 3(8) | 34 |

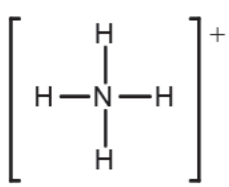
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{34 - 26}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 26 - 2(4) = 18$$



d)

| $NH_4^+$ | N | 4(H) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 4(1) | -1 | 8 |
| Wanted $e^-$ | 8 | 4(2) | | 16 |

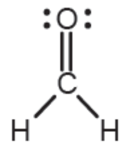
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{16 - 8}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 8 - 2(4) = 0$$



e)

| $H_2CO$ | 2(H) | C | O | Total |
|---|---|---|---|---|
| Valence $e^-$ | 2(1) | 4 | 6 | 12 |
| Wanted $e^-$ | 2(2) | 8 | 8 | 20 |

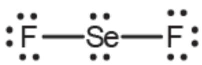
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{20 - 12}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 12 - 2(4) = 4$$



f)

| $SeF_2$ | Se | 2(F) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 2(7) | 20 |
| Wanted $e^-$ | 8 | 2(8) | 24 |

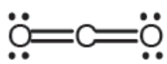
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{24 - 20}{2} = 2$$
$$\# \, e^- = Valence - 2(\#Bonds) = 20 - 2(2) = 16$$



g)

| $CO_2$ | C | 2(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 4 | 2(6) | 16 |
| Wanted $e^-$ | 8 | 2(8) | 24 |

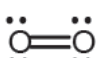
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{24 - 16}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 16 - 2(4) = 8$$



h)

| $O_2$ | 2(O) | Total |
|---|---|---|
| Valence $e^-$ | 2(6) | 12 |
| Wanted $e^-$ | 2(8) | 16 |

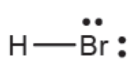
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{16 - 12}{2} = 2$$
$$\# \, e^- = Valence - 2(\#Bonds) = 12 - 2(2) = 8$$



i)

| HBr | H | Br | Total |
|---|---|---|---|
| Valence $e^-$ | 1 | 7 | 8 |
| Wanted $e^-$ | 2 | 8 | 10 |

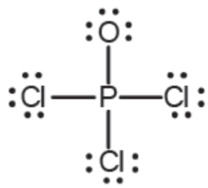
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{10 - 8}{2} = 1$$
$$\# \, e^- = Valence - 2(\#Bonds) = 8 - 2(1) = 6$$



64. a)

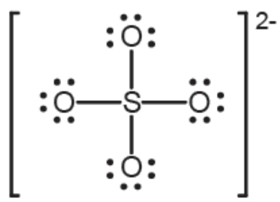
| $POCl_3$ | P | O | 3(Cl) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 6 | 3(7) | 32 |
| Wanted $e^-$ | 8 | 8 | 3(8) | 40 |

$$\#\,Bonds = \frac{Wanted - Valence}{2} = \frac{40-32}{2} = 4$$
$$\#\,e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



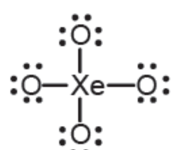
| $SO_4^{2-}$ | S | 4(O) | 2(e-) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 6 | 4(6) | +2(1) | 32 |
| Wanted $e^-$ | 8 | 4(8) | | 40 |

$$\#\,Bonds = \frac{Wanted - Valence}{2} = \frac{40-32}{2} = 4$$
$$\#\,e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



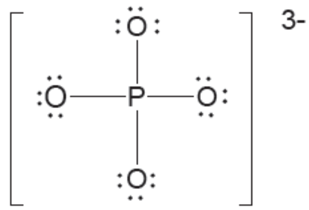
| $XeO_4$ | Xe | 4(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 8 | 4(6) | 32 |
| Wanted $e^-$ | 8 | 4(8) | 40 |

$$\#\,Bonds = \frac{Wanted - Valence}{2} = \frac{40-32}{2} = 4$$
$$\#\,e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



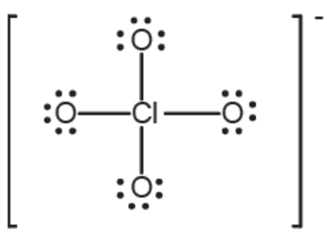
| $PO_4^{3-}$ | P | 4(O) | 3($e^-$) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 4(6) | +3(1) | 32 |
| Wanted $e^-$ | 8 | 4(8) | | 40 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



| $ClO_4^-$ | Cl | 4(O) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 7 | 4(6) | +1 | 32 |
| Wanted $e^-$ | 8 | 4(8) | | 40 |

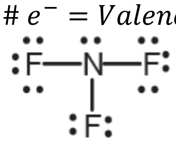
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



b)

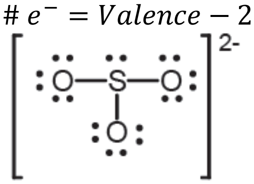
| $NF_3$ | N | 3(F) | Total |
|---|---|---|---|
| Valence $e^-$ | 5 | 3(7) | 26 |
| Wanted $e^-$ | 8 | 3(8) | 32 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32 - 26}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 26 - 2(3) = 20$$



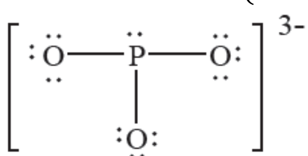
| $SO_3^{2-}$ | S | 3(O) | 2($e^-$) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 6 | 3(6) | +2(1) | 26 |
| Wanted $e^-$ | 8 | 3(8) | | 32 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32 - 26}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 26 - 2(3) = 20$$



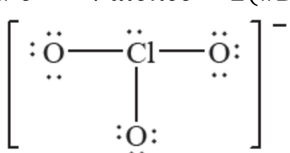
| $PO_3^{2-}$ | P | 3(O) | 2($e^-$) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 6 | 3(6) | +2(1) | 26 |
| Wanted $e^-$ | 8 | 3(8) | | 32 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32 - 26}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 26 - 2(3) = 20$$



| $ClO_3^-$ | Cl | 3(O) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 7 | 3(6) | +1 | 26 |
| Wanted $e^-$ | 8 | 3(8) | | 32 |

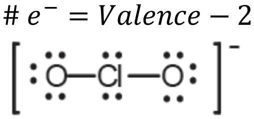
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32 - 26}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 26 - 2(3) = 20$$



c)

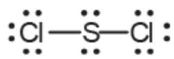
| $ClO_2^-$ | Cl | 2(O) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 7 | 2(6) | +1 | 20 |
| Wanted $e^-$ | 8 | 2(8) | | 24 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{24 - 20}{2} = 2$$
$$\# \, e^- = Valence - 2(\#Bonds) = 20 - 2(2) = 16$$



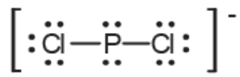
| $SCl_2$ | S | 2(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 2(7) | 20 |
| Wanted $e^-$ | 8 | 2(8) | 24 |

$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{24-20}{2} = 2$$
$$\# e^- = Valence - 2(\#Bonds) = 20 - 2(2) = 16$$



| $PCl_2^-$ | P | 2(Cl) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 2(7) | +1 | 20 |
| Wanted $e^-$ | 8 | 2(8) | | 24 |

$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{24-20}{2} = 2$$
$$\# e^- = Valence - 2(\#Bonds) = 20 - 2(2) = 16$$



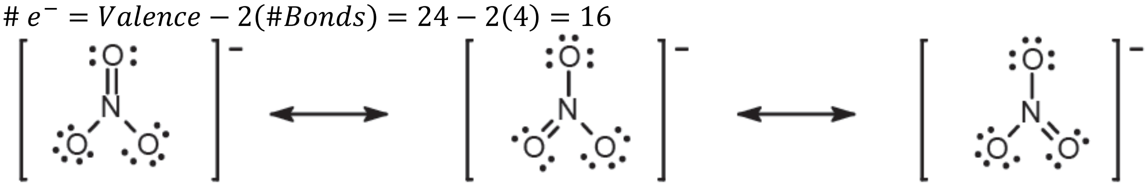
66. a)

| $NO_2^-$ | N | 2(O) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 2(6) | +1 | 18 |
| Wanted $e^-$ | 8 | 2(8) | | 24 |

$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{24-18}{2} = 3$$
$$\# e^- = Valence - 2(\#Bonds) = 18 - 2(3) = 12$$

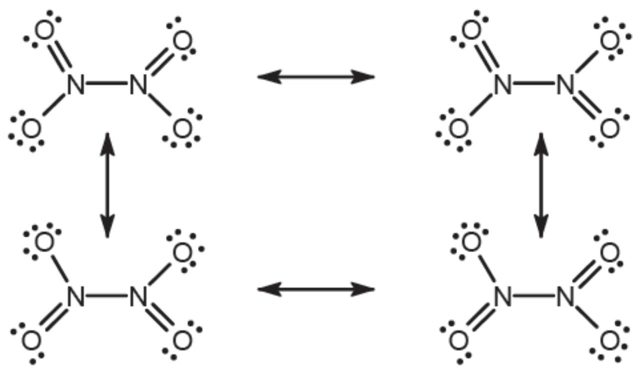
| $NO_3^-$ | N | 3(O) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 3(6) | +1 | 24 |
| Wanted $e^-$ | 8 | 3(8) | | 32 |

$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{32-24}{2} = 4$$
$$\# e^- = Valence - 2(\#Bonds) = 24 - 2(4) = 16$$



| $N_2O_4$ | 2(N) | 4(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 2(5) | 4(6) | 34 |
| Wanted $e^-$ | 2(8) | 4(8) | 48 |

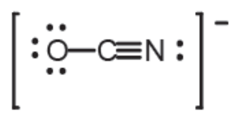
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{48-34}{2} = 7$$
$$\# \, e^- = Valence - 2(\#Bonds) = 34 - 2(7) = 20$$



b)

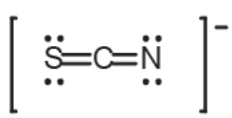
| $OCN^-$ | O | C | N | $e^-$ | Total |
|---|---|---|---|---|---|
| Valence $e^-$ | 6 | 4 | 5 | +1 | 16 |
| Wanted $e^-$ | 8 | 8 | 8 | | 24 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{24-16}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 16 - 2(4) = 8$$



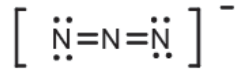
| $SCN^-$ | S | C | N | $e^-$ | Total |
|---|---|---|---|---|---|
| Valence $e^-$ | 6 | 4 | 5 | +1 | 16 |
| Wanted $e^-$ | 8 | 8 | 8 | | 24 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{24-16}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 16 - 2(4) = 8$$



| $N_3^-$ | 3(N) | $e^-$ | Total |
|---|---|---|---|
| Valence $e^-$ | 3(5) | +1 | 16 |
| Wanted $e^-$ | 3(8) | | 24 |

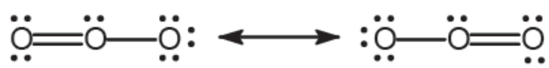
$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{24-16}{2} = 4$$
$$\# e^- = Valence - 2(\#Bonds) = 16 - 2(4) = 8$$



67. Ozone

| $O_3$ | 3(O) | Total |
|---|---|---|
| Valence $e^-$ | 3(6) | 18 |
| Wanted $e^-$ | 3(8) | 24 |

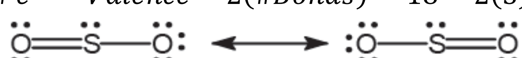
$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{24-18}{2} = 3$$
$$\# e^- = Valence - 2(\#Bonds) = 18 - 2(3) = 12$$



Sulfur dioxide

| $SO_2$ | S | 2(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 2(6) | 18 |
| Wanted $e^-$ | 8 | 2(8) | 24 |

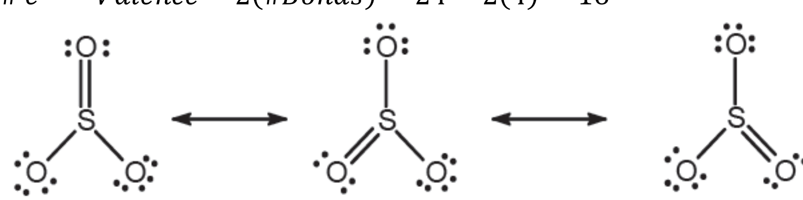
$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{24-18}{2} = 3$$
$$\# e^- = Valence - 2(\#Bonds) = 18 - 2(3) = 12$$



Sulfur Trioxide

| $SO_3$ | S | 3(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 3(6) | 24 |
| Wanted $e^-$ | 8 | 3(8) | 32 |

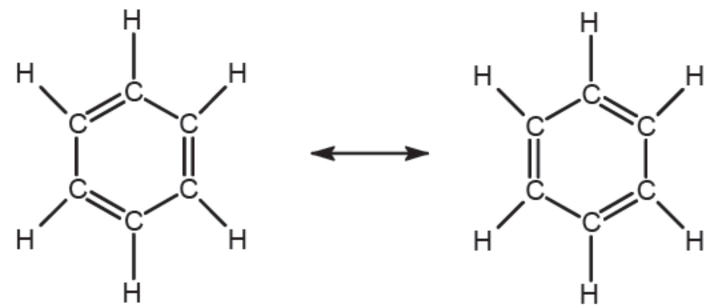
$$\# Bonds = \frac{Wanted - Valence}{2} = \frac{32-24}{2} = 4$$
$$\# e^- = Valence - 2(\#Bonds) = 24 - 2(4) = 16$$



71.

| $C_6H_6$ | 6(C) | 6(H) | Total |
|---|---|---|---|
| Valence $e^-$ | 6(4) | 6(1) | 30 |
| Wanted $e^-$ | 6(8) | 6(2) | 60 |

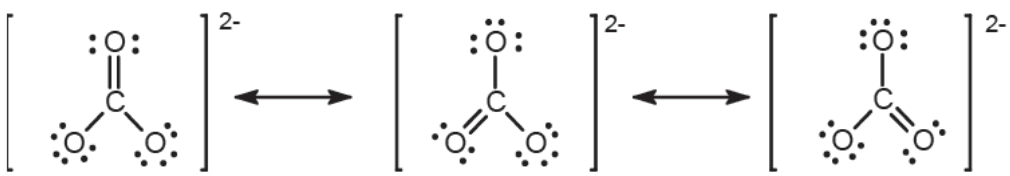
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{60 - 30}{2} = 15$$
$$\# \, e^- = Valence - 2(\#Bonds) = 30 - 2(15) = 0$$



79.

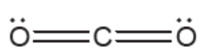
| $CO_3^{2-}$ | C | 3(O) | 2($e^-$) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 4 | 3(6) | +2(1) | 24 |
| Wanted $e^-$ | 8 | 3(8) | | 32 |

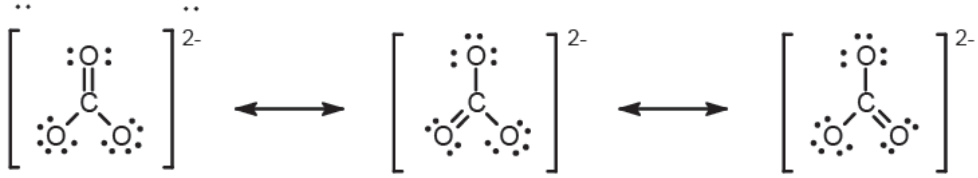
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32 - 24}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 25 - 2(4) = 16$$

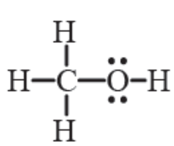


The actual structure of $CO_3^{2-}$ will be a combination of these 3 structures; therefore, the bond length will be between a carbon oxygen single and double bond.

80. Lewis structures for the carbon/oxygen compounds







$CH_3OH$ has a carbon/oxygen single bond; therefore, it will have the longest carbon/oxygen bond length.
$CO_3^{2-}$ has 2 carbon/oxygen single bonds and 1 carbon/oxygen double bond. This results in 3 resonance structures. The carbon/oxygen bond lengths of this system will be shorter than single bonds but longer than double bonds.
$CO_2$ has carbon/oxygen double bonds; therefore, it will have the shorter carbon/oxygen bond length than $CH_3OH$ and $CO_3^{2-}$.
CO has a carbon/oxygen triple bond; therefore, it will have the shortest carbon/oxygen bond length.
Longest to shortest C-O bond length $CH_3OH > CO_3^{2-} > CO_2 > CO$

The shorter the bond the stronger the bond.

Weakest to strongest C-O bond $CH_3OH < CO_3^{2-} < CO_2 < CO$

84.

| Structure | Formal Charge $N_1$ | Formal Charge $N_2$ | Formal Charge O |
|---|---|---|---|
| 1 | -1 | +1 | 0 |
| 2 | 0 | +1 | -1 |
| 3 | -2 | +1 | +1 |

Structure 3 can be eliminated based on formal changes. Formal charges need to be as small as possible. This is not the case for structure 3. In addition, the lowest energy structure is the one in which the negative charge sits on the most electronegative atoms. In structure 3 (which also has the highest overall formal charges) the most electronegative atom (oxygen) has a positive formal charge, which is another reason that this structure is highest in energy, less stable, than structures 1 and 2. The data shows that the nitrogen-oxygen bond length is closest to a nitrogen-oxygen double bond and that the nitrogen-nitrogen bond length is closest to a nitrogen-nitrogen triple bond. Since the bond length are in between structures 1 and 2 this leads to the conclusion that both of these structures must play a role in the overall structure. However, the bond lengths are slightly closer to structure 2 than 1, showing that this resonance structure plays a great role (is lower in energy) than structure 1.

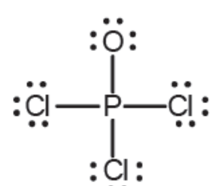
85. All of these structures must obey the octet rule

$$formal\ charge = (valence\ e^-) - (e^-\ surrounding\ atom)$$

a)

| $POCl_3$ | P | O | 3(Cl) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 6 | 3(7) | 32 |
| Wanted $e^-$ | 8 | 8 | 3(8) | 40 |

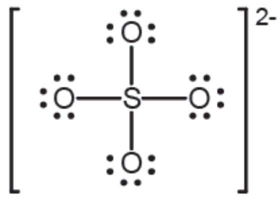
$$\#\ Bonds = \frac{Wanted - Valence}{2} = \frac{40-32}{2} = 4$$
$$\#\ e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



Formal Charges: all Cl = 7-7=0, P = 5-4 = 1, and O = 6-7=-1 b)

| $SO_4^{2-}$ | S | 4(O) | 2($e^-$) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 6 | 4(6) | +2(1) | 32 |
| Wanted $e^-$ | 8 | 4(8) | | 40 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$

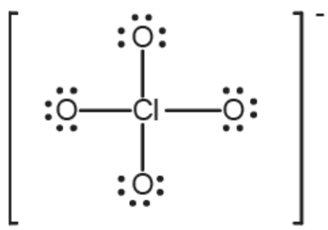


Formal Charges: all O=6-7=-1, and S=6-4=2

c)

| $ClO_4^-$ | Cl | 4(O) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 7 | 4(6) | +1 | 32 |
| Wanted $e^-$ | 8 | 4(8) | | 40 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$

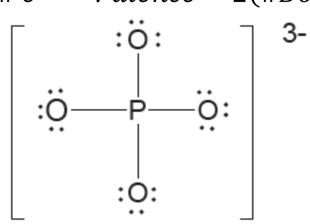


Formal Charge: all O=6-7=-1, and Cl=7-4=3

d)

| $PO_4^{3-}$ | P | 4(O) | 3($e^-$) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 4(6) | +3(1) | 32 |
| Wanted $e^-$ | 8 | 4(8) | | 40 |

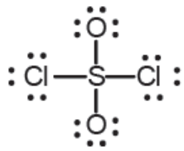
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



Formal Charge: all O=6-7=-1, and P=5-4=1 e)

| $SO_2Cl_2$ | S | 2(O) | 2(Cl) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 6 | 2(6) | 2(7) | 32 |
| Wanted $e^-$ | 8 | 2(8) | 2(8) | 40 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$

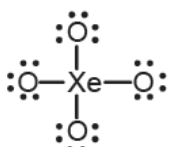


Formal Charge: all O=6-7=-1, all Cl 7-7=0, and S=6-4=2

f)

| $XeO_4$ | Xe | 4(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 8 | 4(6) | 32 |
| Wanted $e^-$ | 8 | 4(8) | 40 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$

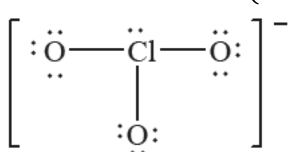


Formal Charge: all O=6-7=-1, and Xe= 8-4=4

g)

| $ClO_3^-$ | Cl | 3(O) | $e^-$ | Total |
|---|---|---|---|---|
| Valence $e^-$ | 7 | 3(6) | +1 | 26 |
| Wanted $e^-$ | 8 | 3(8) | | 32 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32 - 26}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 26 - 2(3) = 20$$

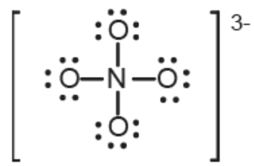


Formal Charge: all O=6-7=-1, and Cl=7-5=2 h)

| $NO_4^{3-}$ | N | 4(O) | 3($e^-$) | Total |
|---|---|---|---|---|
| Valence $e^-$ | 5 | 4(6) | +3(1) | 32 |
| Wanted $e^-$ | 8 | 4(8) | | 40 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$

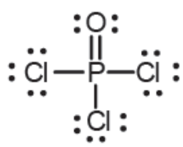
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



Formal Charge: all O=7-6=-1, and N=5-4=1

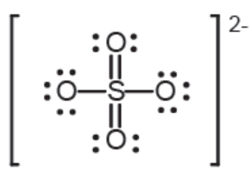
86. Minimize the formal charge in these structures

a)



All formal charges equal 0

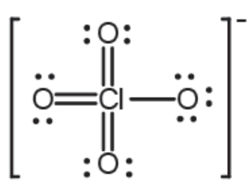
b)



S and the double bonded O's have a formal charges equal 0. The single bonded O's have a formal charges of -1.

Note: There are 6 total resonance structures for $SO_4^{2-}$

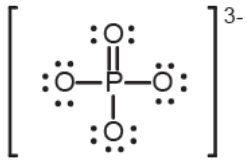
c)



Cl and the double bonded O's have a formal charges equal 0. The single bonded O has a formal charge of -1.

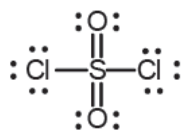
Note: There are 4 total resonance structures for $ClO_4^-$

d)



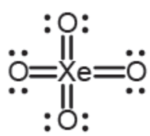
P and the double bonded O have a formal charges equal 0. The single bonded O's have a formal charges of -1.
Note: There are 4 total resonance structures for $PO_4^{3-}$

e)



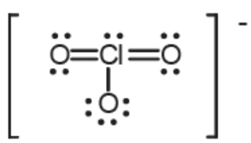
All formal charges equal 0

f)



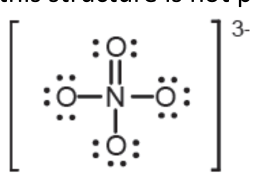
All formal charges equal 0

g)



Cl and the double bonded O's have a formal charges equal 0. The single bonded O has a formal charge of -1.
Note: There are 3 total resonance structures for $ClO_3^-$

h) Although the following structure can be drawn and all of the formal charges would be 0 this structure is not possible because N cannot expand its octet.

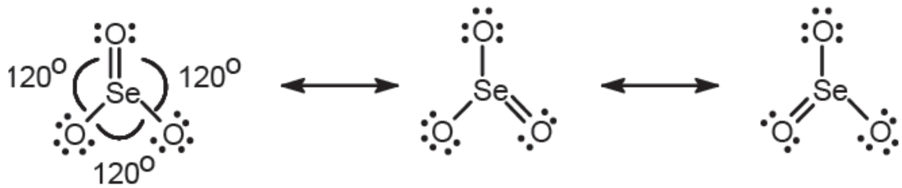


Note: If this structure could be drawn there would be a total of 4 resonance structures for $NO_4^{3-}$

96. a)

| $SeO_3$ | Se | 3(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 3(6) | 24 |
| Wanted $e^-$ | 8 | 3(8) | 32 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32-24}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 24 - 2(4) = 16$$

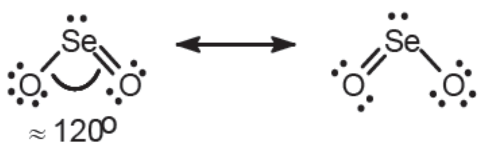



Shape: Trigonal Planer Angle: 120˚

b)

| $SeO_2$ | Se | 2(O) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 2(6) | 18 |
| Wanted $e^-$ | 8 | 2(8) | 24 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{24-18}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 18 - 2(3) = 12$$

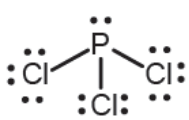



Shape: Bent Angle: <120˚

c)

| $PCl_3$ | P | 3(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 5 | 3(7) | 26 |
| Wanted $e^-$ | 8 | 3(8) | 32 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{32-26}{2} = 3$$
$$\# \, e^- = Valence - 2(\#Bonds) = 26 - 2(3) = 20$$

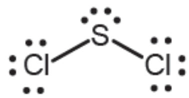


Shape: Trigonal Pyramidal Angle: <109.5˚

d)

| $SCl_2$ | S | 2(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 2(7) | 20 |
| Wanted $e^-$ | 8 | 2(8) | 24 |

$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{24 - 20}{2} = 2$$
$$\# \, e^- = Valence - 2(\#Bonds) = 20 - 2(2) = 16$$

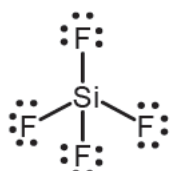


Shape: Bent Angle: <109.5˚

e)

| $SiF_4$ | Si | 4(F) | Total |
|---|---|---|---|
| Valence $e^-$ | 4 | 4(7) | 32 |
| Wanted $e^-$ | 8 | 4(8) | 40 |

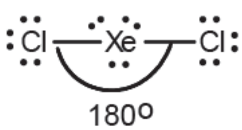
$$\# \, Bonds = \frac{Wanted - Valence}{2} = \frac{40 - 32}{2} = 4$$
$$\# \, e^- = Valence - 2(\#Bonds) = 32 - 2(4) = 24$$



Shape: Tetrahedral Angle: 109.5˚

99. a)

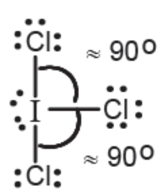
| $XeCl_2$ | Xe | 2(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 8 | 2(7) | 22 |




Shape: Linear Angle: 180˚

b)

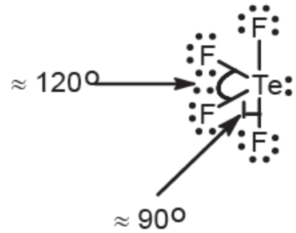
| $ICl_3$ | I | 3(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 7 | 3(7) | 28 |




Shape: T-Shaped Angles: <90˚

c)

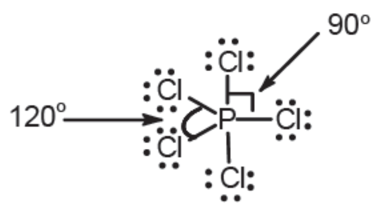
| $TeF_4$ | Te | 4(F) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 4(7) | 28 |




Shape: Sea-Saw Angles: <90˚ and <120˚

d)

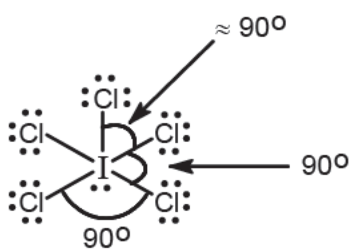
| $PCl_5$ | P | 5(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 5 | 5(7) | 40 |




Shape: Trigonal Bipyramidal Angle: 90˚ and 120˚

100. a)

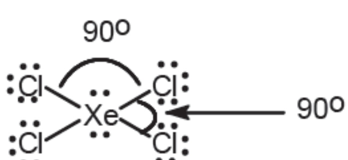
| $ICl_5$ | I | 5(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 7 | 5(7) | 42 |




Shape: Square Pyramidal Angles: 90˚ and <90˚

b)

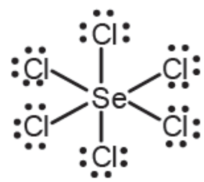
| $XeCl_4$ | Xe | 4(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 8 | 4(7) | 36 |




Shape: Square Planar Angle: 90˚

c)

| $SeCl_6$ | Se | 6(Cl) | Total |
|---|---|---|---|
| Valence $e^-$ | 6 | 6(7) | 48 |



Shape: Octahedral Angle: 90˚

101. $SeO_2$, $PCl_3$, and $SCl_2$ all have net dipole moments which makes them polar.

102. $ICl_3$, $TeF_4$, and $ICl_5$ all have net dipole moments which makes them polar.