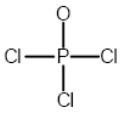
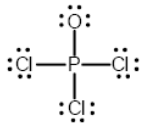
Date	Lecture	Reading	Problems
Wednesday, 11/17	Lewis structures, resonance, formal charge	Sections 13.6, 13.9 – 13.12	Ch. 13: #52, 54, 72, 74, 98
Friday, 11/19	VSEPR, Molecular dipoles	Section 13.13	Ch. 13: #76, 80

Lewis Structures and Resonance

52. a. $POCl_3$ has 5 + 6 + 3(7) = 32 valence electrons.



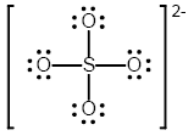
Skeletal structure



Lewis structure

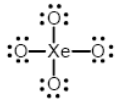
Note: This structure uses all 32 e^- while satisfying the octet rule for all atoms. This is a valid Lewis structure.

SO_4^{2-} has 6 + 4(6) + 2 = 32 valence electrons.

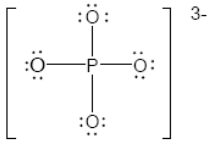


Note: A negatively charged ion will have additional electrons to those that come from the valence shell of the atoms.

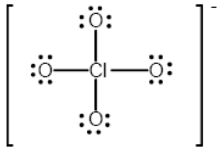
XeO_4, 8 + 4(6) = 32 e^-



PO_4^{3-}, 5 + 4(6) + 3 = 32 e^-

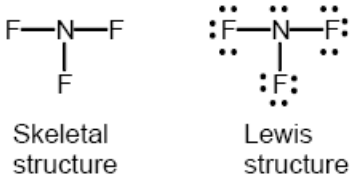


ClO_4^- has 7 + 4(6) + 1 = 32 valence electrons.

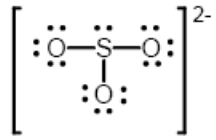


Note: All these species have the same number of atoms and the same number of valence electrons. They also have the same Lewis structure.

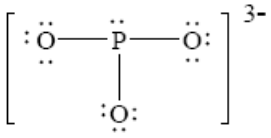
b. NF_3 has 5 + 3(7) = 26 valence electrons. SO_3^{2-}, 6 + 3(6) + 2 = 26 e^-



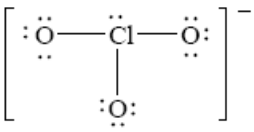
Skeletal structure Lewis structure



PO_3^{3-}, 5 + 3(6) + 3 = 26 e^-

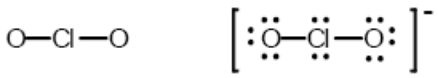


ClO_3^-, 7 + 3(6) + 1 = 26 e^-



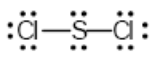
Note: Species with the same number of atoms and valence electrons have similar Lewis structures.

c. ClO_2^- has 7 + 2(6) + 1 = 20 valence electrons.

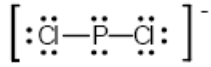


Skeletal structure Lewis structure

SCl_2, 6 + 2(7) = 20 e^-



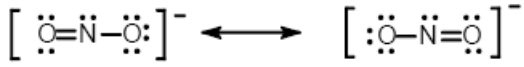
PCl_2^-, 5 + 2(7) + 1 = 20 e^-



Note: Species with the same number of atoms and valence electrons have similar Lewis structures.

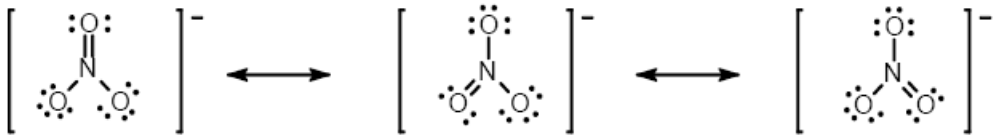
54. a. NO_2^- has 5 + 2(6) + 1 = 18 valence electrons. The skeletal structure is: O – N – O

To get an octet about the nitrogen and only use 18 e^-, we must form a double bond to one of the oxygen atoms.

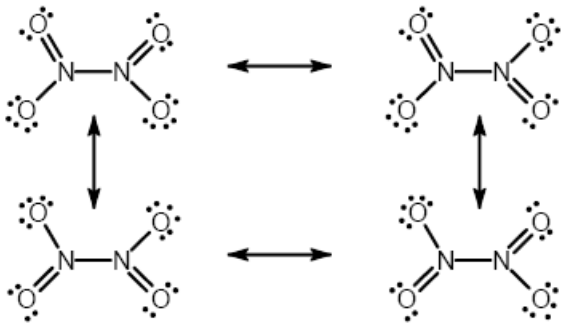


Because there is no reason to have the double bond to a particular oxygen atom, we can draw two resonance structures. Each Lewis structure uses the correct number of electrons and satisfies the octet rules, so each is a valid Lewis structure. Resonance structures occur when you have multiple bonds that can be in various positions. We say the actual structure is an average of these two resonance structures.

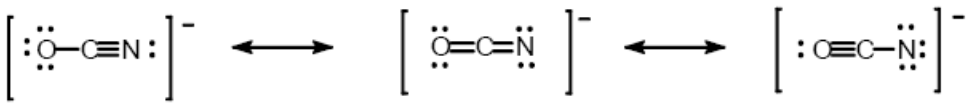
NO_3^- has 5 + 3(6) + 1 = 24 valence electrons. We can draw three resonance structures for NO_3^-, with the double bond rotating between the three oxygen atoms.



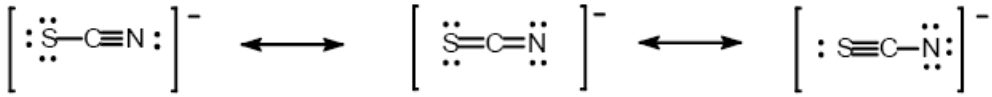
N_2O_4 has 2(5) + 4(6) = 34 valence electrons. We can draw four resonance structures for N_2O_4.



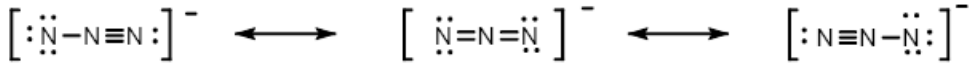
b. OCN^- has 6 + 4 + 5 + 1 = 16 valence electrons. We can draw three resonance structures for OCN^-.



SCN^- has 6 + 4 + 5 + 1 = 16 valence electrons. Three resonance structures can be drawn.

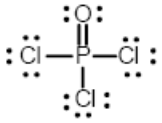


N_3^- has 3(5) + 1 = 16 valence electrons. As with OCN^- and SCN^-, three different resonance structures can be drawn.



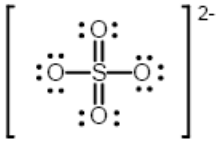
72. For SO_4^{2-}, ClO_4^-, PO_4^-, and ClO_3^-, only one of the possible resonance structures is drawn.

a. Must have five bonds to P to minimize formal charge of P. The best choice is to form a double bond to O since this will give O a formal charge of zero and single bonds to Cl for the same reason.



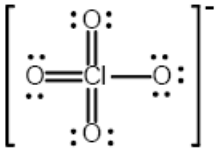
P, FC = 0

b. Must form six bonds to S to minimize formal charge of S.



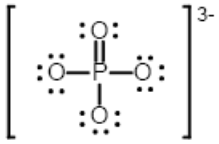
S, FC = 0

c. Must form seven bonds to Cl to minimize formal charge.



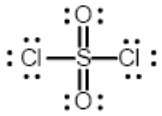
Cl, FC = 0

d. Must form five bonds to P to to minimize formal charge.



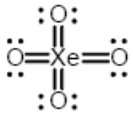
P, FC = 0

e.



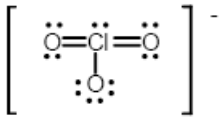
S, FC = 0

f.



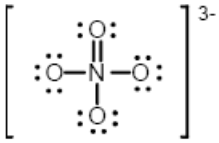
Xe, FC = 0

g.



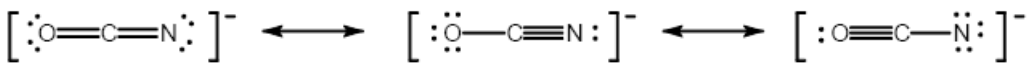
Cl, FC = 0

h. We can't . The following structure has a zero formal charge for N:



but N does not expand its octet. We wouldn't expect this resonance form to exist.

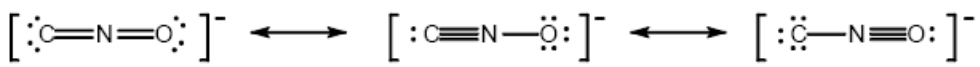
74. OCN^- has 6 + 4 + 5 + 1 = 16 valence electrons.



Formal charge	0	0	-1		-1	0	0		+1	0	-2

Only the first two resonance structures should be important. The third places a positive formal charge on the most electronegative atom in the ion and a -2 formal charge on N.

CNO^-:



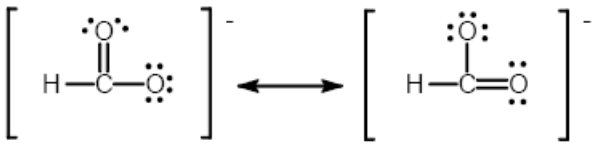
Formal charge	-2	+1	0	-1	+1	-1	-3	+1	+1

All the resonance structures for fulminate (CNO^-) involve greater formal charges than in cyanate (OCN^-), making fulminate more reactive (less stable).

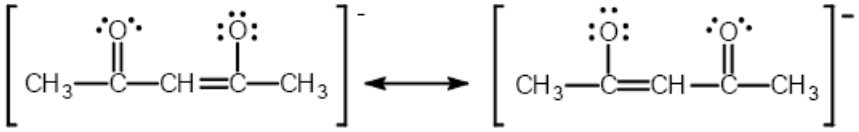
Additional Exercises

98. If we can draw resonance forms for the anion after loss of H^+, we can argue that the extra stability of the anion causes the proton to be more readily lost, i.e., makes the compound a better acid.

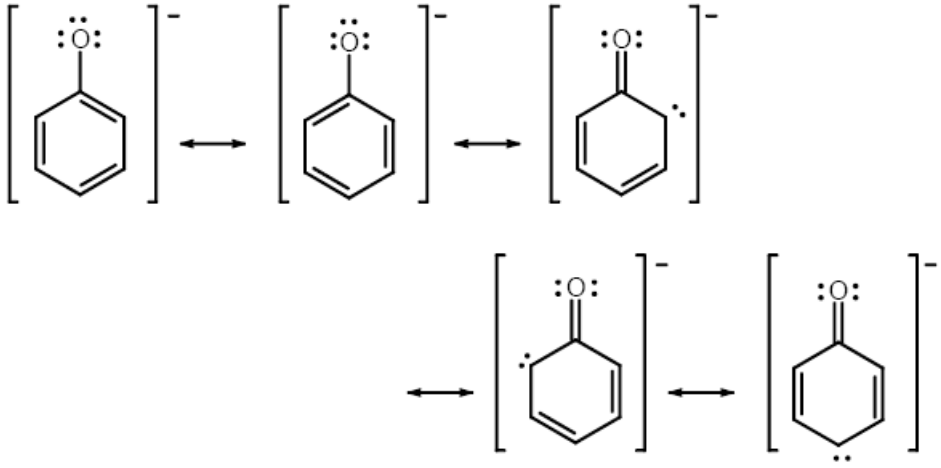
a.



b.



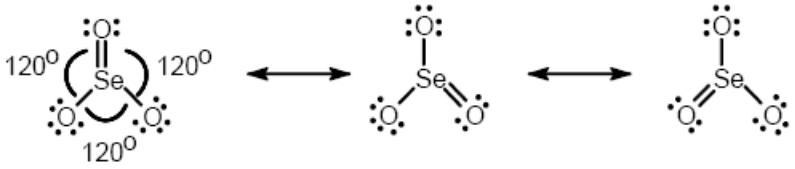
c.



In all three cases, extra resonance forms can be drawn for the anion that are not possible when the H^+ is present, which leads to enhanced stability.

Molecular Structure and Polarity

76. a. SeO_3, $6 + 3(6) = 24\ e^-$



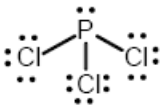
SeO_3 has a trigonal planar molecular structure with all bond angles equal to 120°. Note that any one of the resonance structures could be used to predict molecular structure and bond angles.

b. SeO_2, $6 + 2(6) = 18\ e^-$

SeO_2 has a V-shaped molecular structure. We would expect the bond angle to be approximately 120° as expected for trigonal planar geometry.

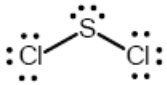
Note: Both SeO_3 and SeO_2 structures have three effective pairs of electrons about the central atom. All the structures are based on a trigonal planar geometry, but only SeO_3 is described as having a trigonal planar structure. Molecular structure always describes the relative positions of the atoms.

c. PCl_3 has $5 + 3(7) =$ 26 valence electrons.



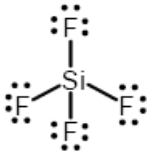
Trigonal pyramid; all angles are <109.5°.

d. SCl_2 has $6 + 2(7) =$ 20 valence electrons



V-shaped; angle is <109.5°.

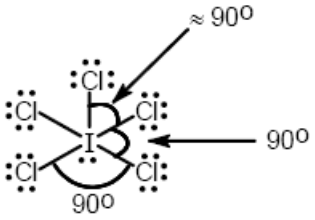
e. SiF_4 has $4 + 4(7) = 32$ valence electrons.



Tetrahedral; all angles are 109.5°.

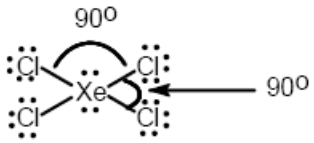
Note: In PCl_3, SCl_2, and SiF_4, there are four pairs of electrons about the central atom in each case. All the structures are based on a tetrahedral geometry, but only SiF_4 has a tetrahedral structure. We consider only the relative positions of the atoms when describing the molecular structure.

80. a. ICl_5, $7 + 5(7) = 42$ e⁻



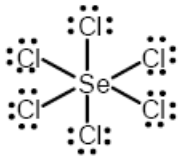
Square pyramid, ≈ 90° bond angles

b. $XeCl_4$, $8 + 4(7) = 36$ e⁻



Square planar, 90° bond angles

c. $SeCl_6$ has $6 + 6(7) = 48$ valence electrons.

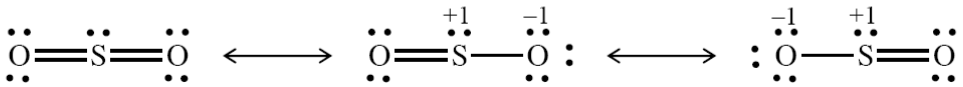


Octahedral, 90° bond angles

Note: All these species have six pairs of electrons around the central atom. All three structures are based on the octahedron, but only $SeCl_6$ has an octahedral molecular structure.

Assignment 11 Challenge Problem – Solutions

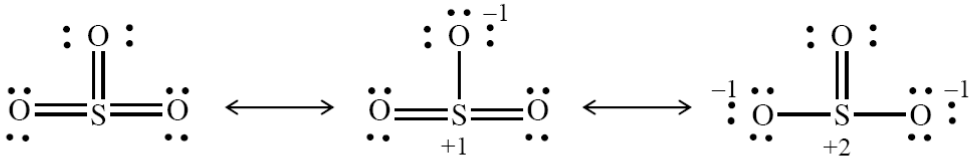
1. a.



best (all FC=0) okay okay

b. bent, with ∠OSO < 120°

2. a.



(3 of these) (3 of these)

best (all FC=0) okay bad

b. trigonal planar, with ∠OSO = 120°

c. The structure that has all zero formal charges requires supervalent O, which is not possible. The structure that obeys the octet rule has a formal charge of +2 on the central O atom, which is not acceptable.

3. a.

okay okay

b. bent, with ∠ONO < 120°

c. NO_2 is a radical in which N has only 7 electrons.

d. Draw and evaluate all reasonable resonance structure(s) for NO_2^+.

e. The nitrogen–oxygen bond (BO = 2) within NO_2^+ is shorter than the nitrogen–oxygen bond (BO = 1.5) within NO_2.