Problem Set #12

CHEM101A: General College Chemistry

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November 7, 2025

11 Topic F Problem 11

There are two ions that have the empirical formula CNO^-. The cyanate ion has the three atoms in the order N-C-O, while the fulminate ion has the three atoms in the order C-N-O.

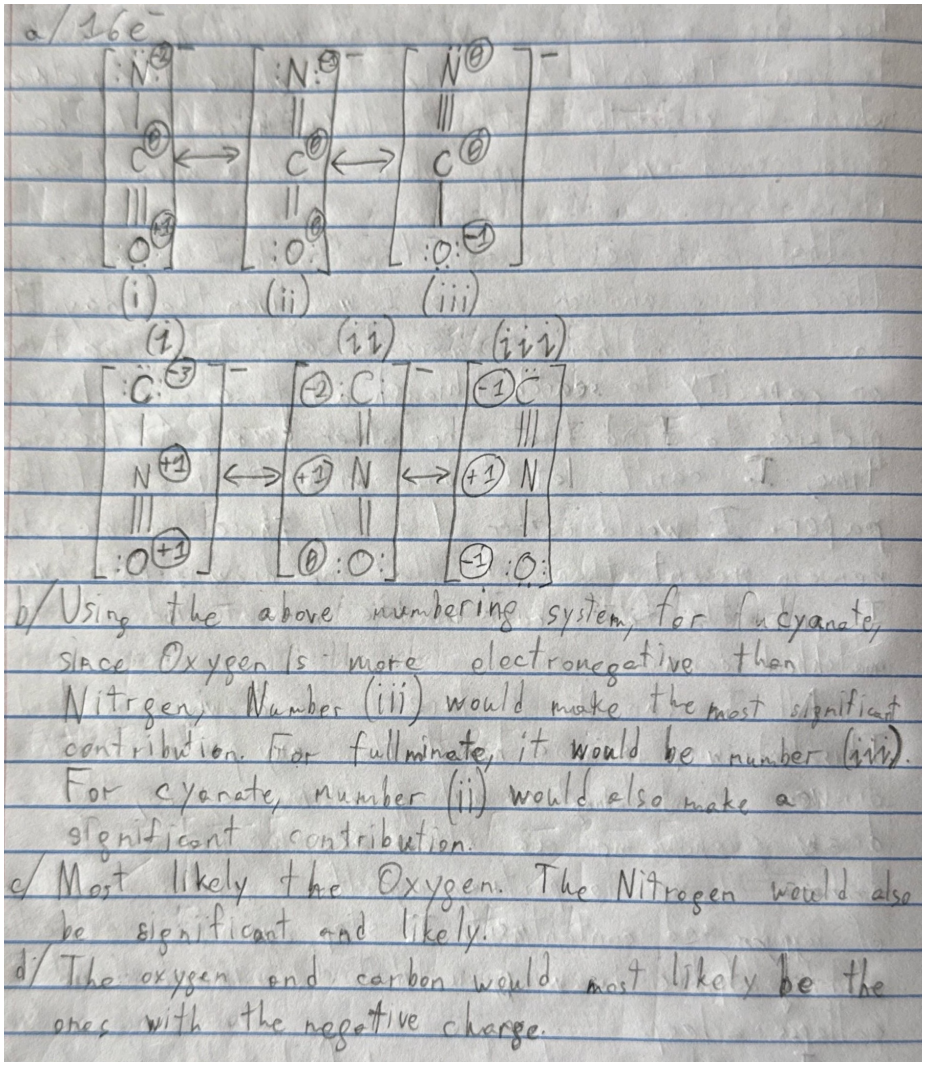
a) Draw all of the resonance structures that satisfy the octet rule for each ion. Include all non-zero formal charges in your structures.

b) Based on formal charges, which of these resonance structures would you expect to make a significant contribution to the actual structures of the cyanate and fulminate ions?

c) Based on your resonance structures for the cyanate ion, which atom (or atoms) carries the negative charge?

d) Repeat part c for the fulminate ion.

11.1 Solution



12 Topic F Problem 12

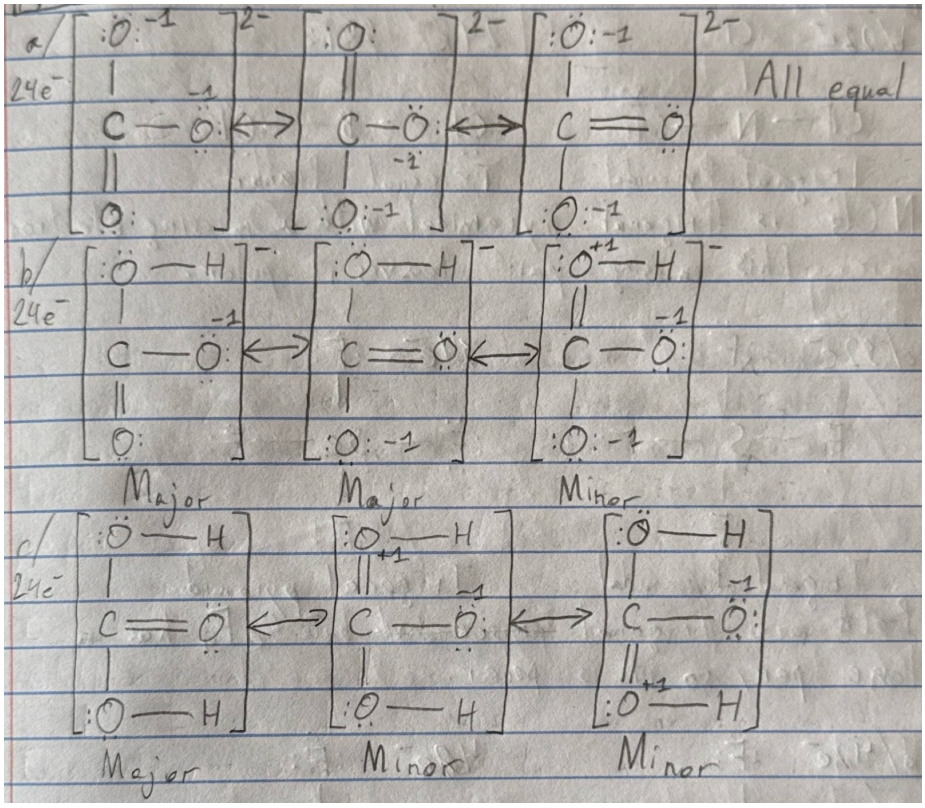
Draw all of the reasonable resonance structures that satisfy the octet rule for each of the following substances, and tell which structures will be major contributors to the actual structure of the molecule or ion.

a) CO_3^{2-}

b) HCO_3^{-} (the H is attached to one of the O atoms in CO_3^{2-})

c) H_2CO_3 (each H is attached to one of the O atoms in CO_3^{2-})

12.1 Solution



13 Topic F Problem 13

Each of the three substances in the previous problem contains three carbon-oxygen bonds. For each substance, which carbon-oxygen bonds are the same length?

13.1 Solution

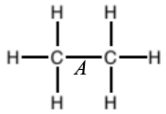
a/ All three are the same length.

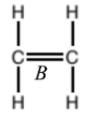
b/ The ones not with oxygens not bonded to hydrogens.

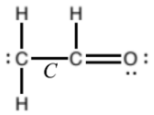
c/ The ones with oxygens bonded to hydrogens.

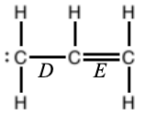
14 Topic F Problem 14

Rank the bonds labeled A through E in order of carbon-carbon bond distance, starting with the shortest bond distance. Be sure to consider resonance!







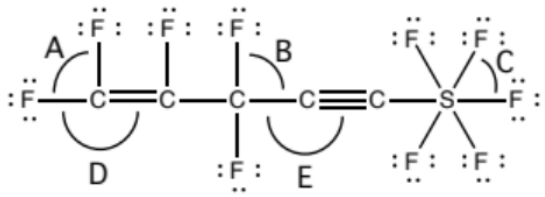


14.1 Solution

$$B < C < D = E < A \tag{1}$$

15 Topic F Problem 15

What are the approximate values (in degrees) for the bond angles labeled A through E in the molecule below?



15.1 Solution

A: 120°

B: 109.5°

C: 90°

D: 120°

E: 180°

16 Topic F Problem 16

For each of the following pairs of molecules, one molecule is polar while the other is not. Tell which molecule is polar, and justify your answer using Lewis structures and VSEPR.

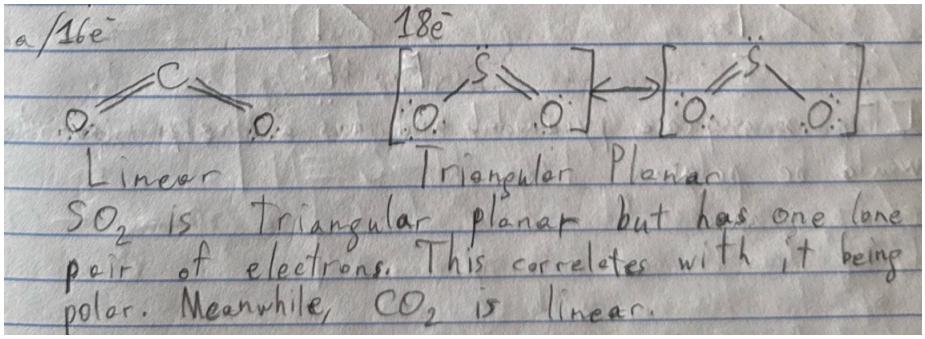
a) CO_2 and SO_2

b) NCl_3 and BCl_3

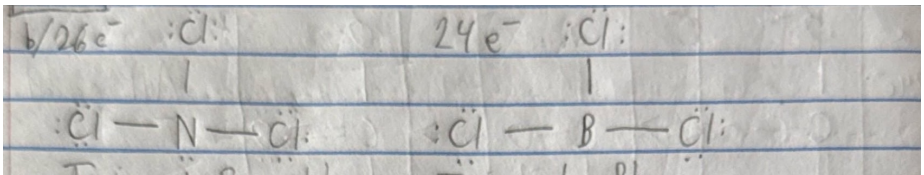
c) SiF_4 and SeF_4

d) IF_5 and PF_5

16.1 Solution



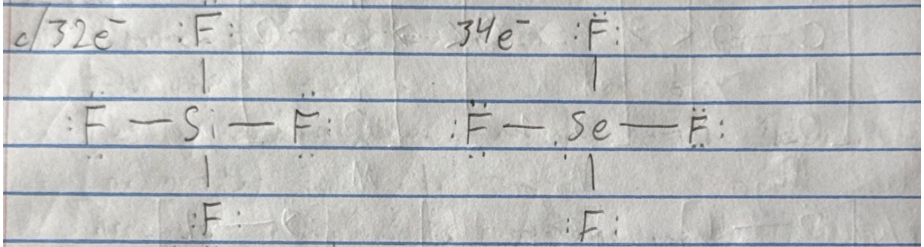
b/ 26 e^- 24 e^-



Trigonal Pyramidal Trigonal Planar

NCl_3 is trigonal pyramidal with a missing electron pair. This missing pair leaves it polar.

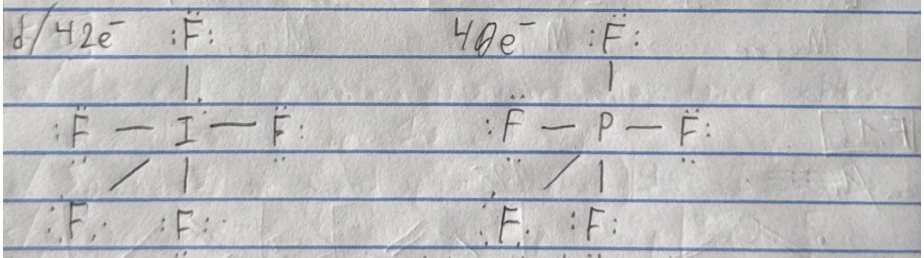
c/ 32 e^- 34 e^-



Trigonal Pyramidal Trigonal pyramid

Both are trigonal ~~or see-saw~~ but SeF_4 has a lone pair, so it is polar.

d/ 42 e^- 40 e^-



IF_4 is square pyramidal and has a lone pair, so it would be polar.

17 Topic F Problem 17

What is the hybridization on each of the following atoms?

a) The nitrogen atom in NH_3

b) The phosphorus atom in PF_5

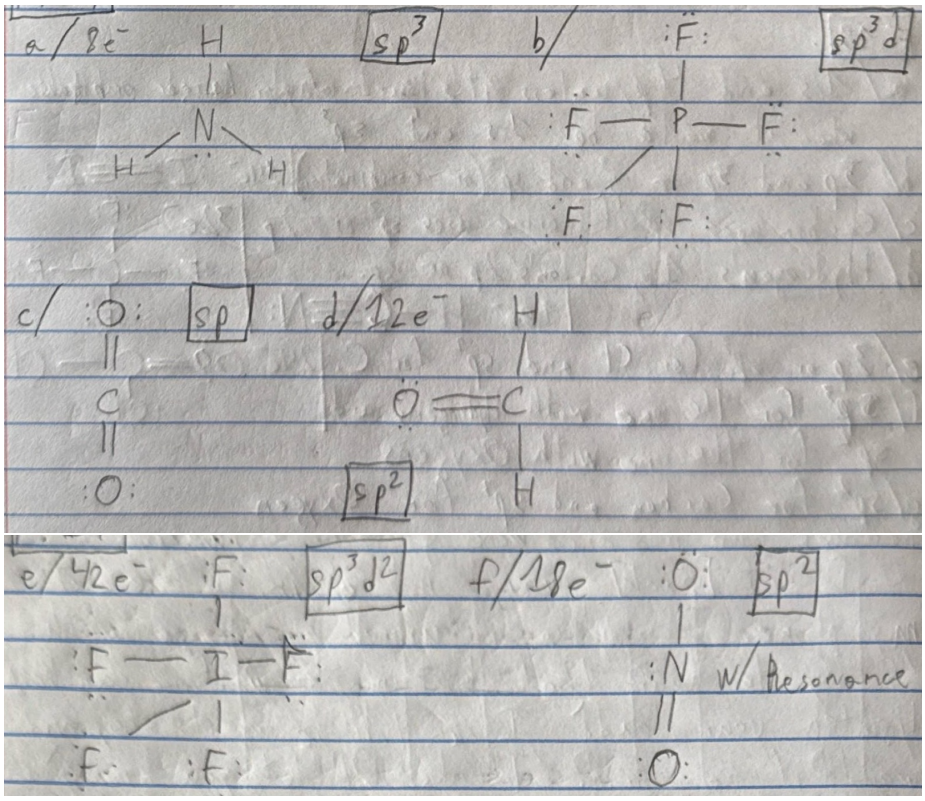
c) The carbon atom in CO_2

d) The carbon atom in CH_2O

e) The iodine atom in IF_5

f) The nitrogen atom in NO_2^-

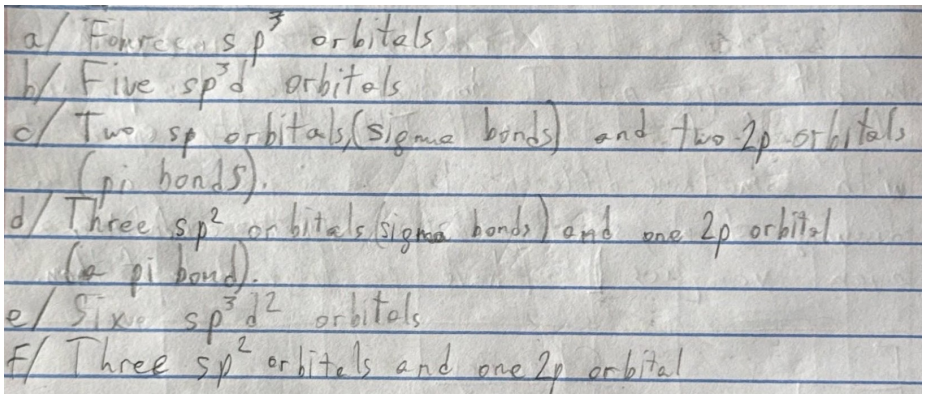
17.1 Solution



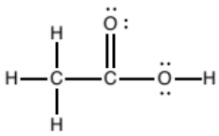
18 Topic F Problem 18

List all of the valence orbitals in each of the atoms listed in the previous problem, and tell how many of each there are. Do not list orbitals on the outer atoms.

18.1 Solution



19 Topic F Problem 19



According to the valence-bond model, what atomic orbitals overlap to form each of the following chemical bonds?

a) The H−Br bond in HBr

b) The I−I bond in I_2

c) A C−F bond in CF_4

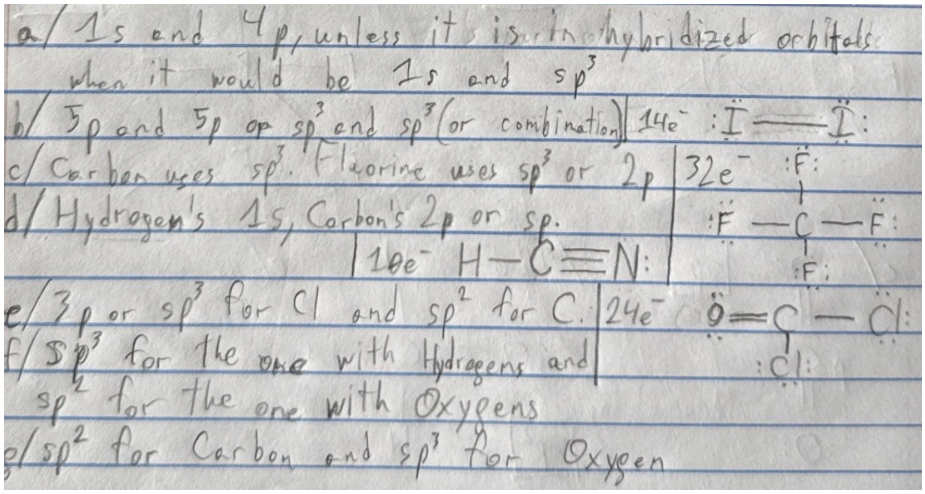
d) The C−H bond in HCN

e) A C−Cl bond in $COCl_2$

f) The C−C bond in acetic acid (the molecule on the right)

g) The C−O single bond in acetic acid

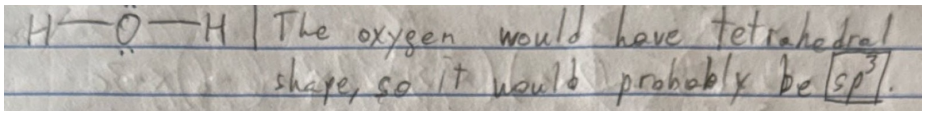
19.1 Solution



20 Topic F Problem 20

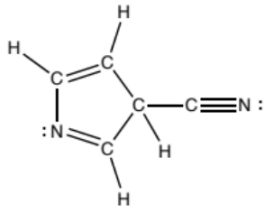
According to the valence-bond model, what atomic orbitals hold the nonbonding electrons in a molecule of water?

20.1 Solution



21 Topic F Problem 21

Questions a through d (on the next page) refer to the molecule below.



a) How many sigma bonds and how many pi bonds are there in this molecule?

b) What atomic orbitals form the carbon-nitrogen double bond? Tell whether each orbital is involved in a sigma bond or a pi bond.

c) What atomic orbitals form the carbon-nitrogen triple bond? Tell whether each orbital is involved in a sigma bond or a pi bond.

d) What atomic orbitals contain the nonbonding electrons?

21.1 Solution

a/ Eleven sigma bonds and four pi bonds.

b/ One sp^2 (on Carbon) to sp^2 (on Nitrogen) in a Sigma bond. One 2p (on Nitrogen) to 2p (on Carbon) in a pi bond.

c/ One sp (Carbon) to p (Nitrogen) in a sigma bond and two 2p to 2p in pi bonds.

d/ In the double bonded Nitrogen, sp^2. In the triple bond Nitrogen, 2s.

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