Problem Set #11

CHEM101A: General College Chemistry

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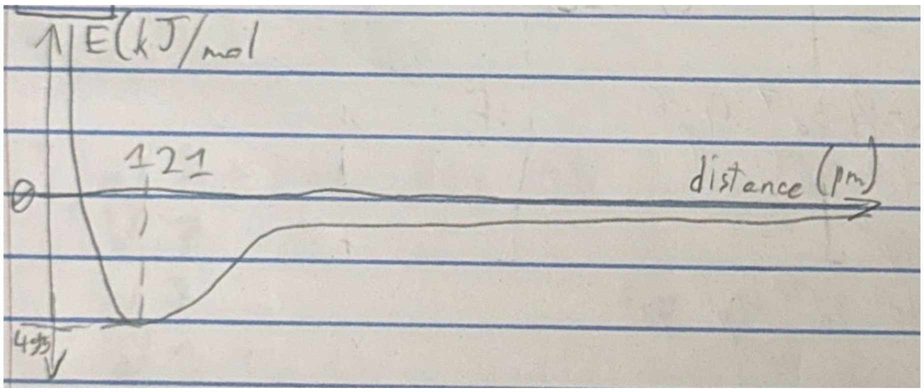
1 Topic F Problem 1

Draw a bond energy diagram (a graph of potential energy versus distance between the nuclei) for the bond in O_2, which has a bond energy of 495 kJ/mol and a bond distance of 121 pm.

1.1 Solution



2 Topic F Problem 2

Draw Lewis structures for each of the following molecules. For each molecule, the first atom in the formula is the central atom and all other atoms are bonded to it.

a) CH_4

b) PCl_3

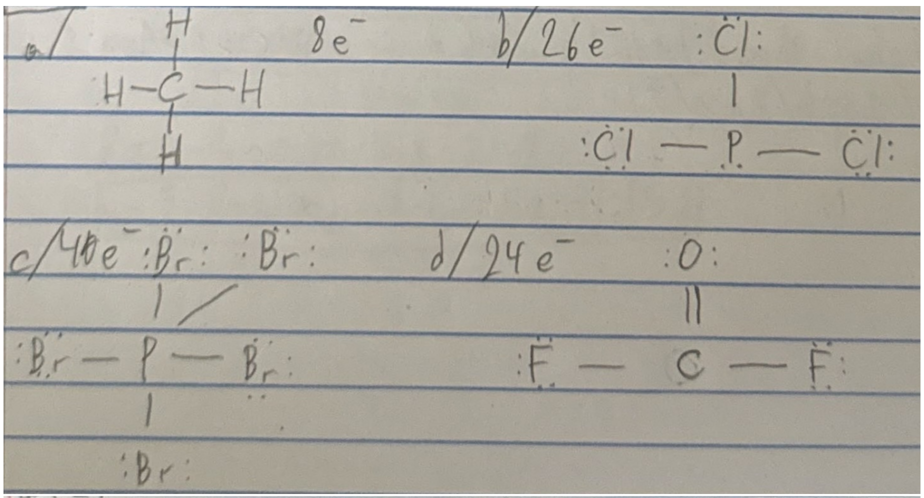
c) PBr_5

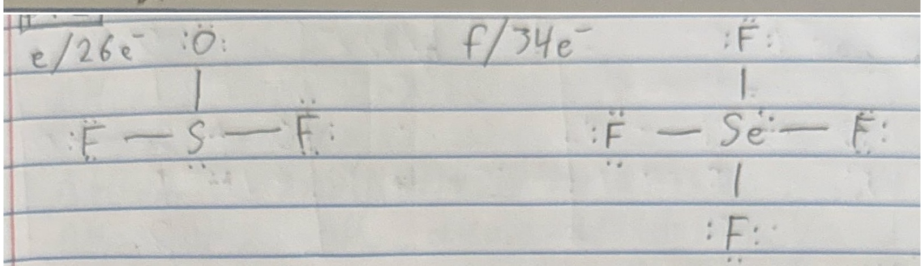
d) COF_2

e) SOF_2

f) SeF_4

2.1 Solution





3 Topic F Problem 3

Draw Lewis structures for each of the following polyatomic ions. If there are multiple resonance structures for an ion, you only need to draw one of the resonance structures.

a) NO_2^-

b) NH_4^+

c) BF_4^-

d) CO_3^{2-}

e) CN^-

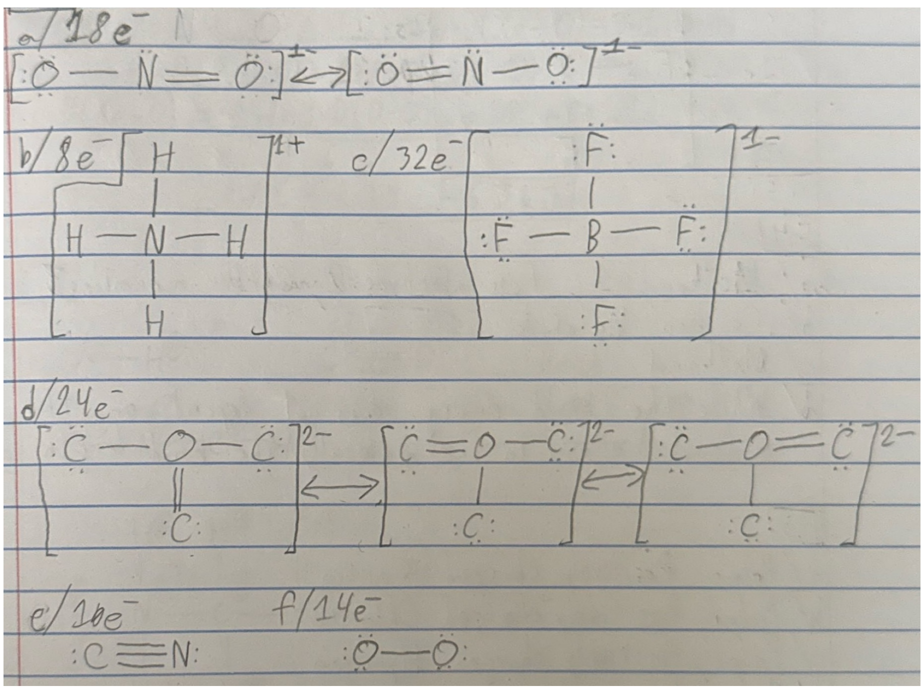
f) O_2^{2-}

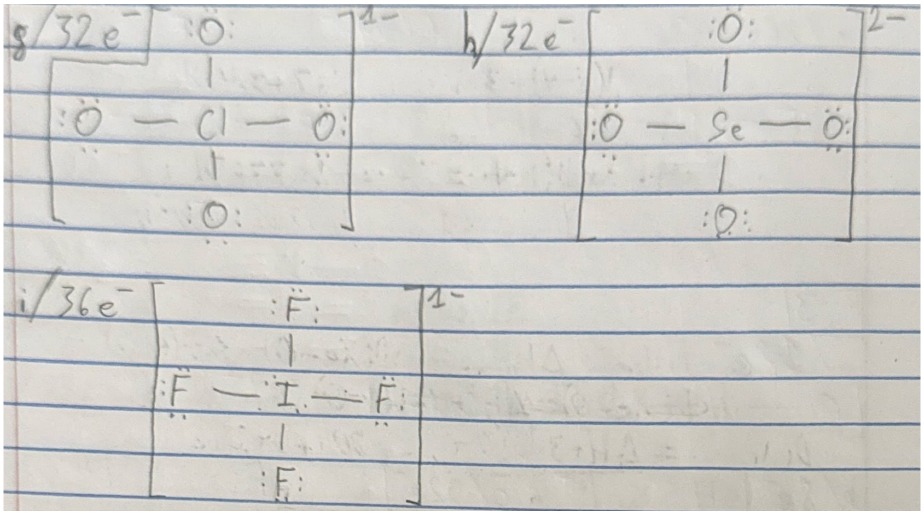
g) ClO_4^-

h) SeO_4^{2-}

i) IF_4^-

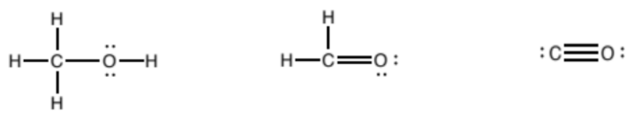
3.1 Solution




g/32e⁻
1−
h/32e⁻
2−
i/36e⁻
1−

4 Topic F Problem 4

Consider each of the following molecules:



methanol *formaldehyde* *carbon monoxide*

a) What is the bond order of the carbon-oxygen bond in each molecule?

b) Which molecule has the largest carbon-oxygen bond energy?

c) Which molecule has the largest carbon-oxygen bond distance?

d) Would you expect the carbon-hydrogen bond distances in methanol and formaldehyde to be equal, or will they be significantly different? If they are different, which molecule should have the larger C-H bond distances?

4.1 Solution

a/ Methanol: 1; Formaldehyde: 2; Carbon monoxide: 3

b/ Carbon Monoxide

c/ Methanol

d/ While the bond energy does depend on the other ~~molecules~~ atoms in the molecule, the bond length $\boxed{\text{does not}}$.

5 Topic F Problem 5

For each of the bond types in parts a through d below, answer the following questions. You may refer to the table of electronegativity values in the textbook.

- Are these bonds polar?
- If they are polar, which atom is positively charged (if any)?

a) The C−Cl bonds in CCl_4

b) The O−Cl bonds in OCl_2

c) The C−H bonds in CH_4

d) The C−C bond in C_2H_6

5.1 Solution

a/ Polar; Positively charged Carbon
b/ Polar; Positively charged Chlorine
c/ Polar; Positively charged Hydrogen
d/ Not polar
Table found in 6.1.2

6 Topic F Problem 6

Using the bond dissociation energy values in the text, calculate an approximate value of ΔH for the reaction: $N_2\,(g) + 3\,H_2\,(g) \longrightarrow 2\,NH_3\,(g)$.

6.1 Solution

Table found in 6.1.5

$$\Delta H_{deformation} = D(N-N) + 3 \times D(H-H) = 167 + 3 \times 432$$

$$= 1463\ kJ/mol$$

$$\Delta H_{reformation} = 3 \times D(N-H) = 3 \times 391 = 1173\ kJ/mol$$

$$\Delta H_{rxn} = \Delta H_{deform} - \Delta H_{reform} = 1463 - 1173 = \boxed{290\ kJ/mol}$$

7 Topic F Problem 7

Xenon is one of the "inert gases", but it can form a number of compounds, including xenon trioxide (XeO3). When heated, xenon trioxide breaks down explosively into the elements:

$$2\,\mathrm{XeO_3}\,(g) \longrightarrow 2\,\mathrm{Xe}\,(g) + 3\,\mathrm{O_2}\,(g), \Delta\mathrm{H} = -804\,\mathrm{kJ}$$

Use this value and the bond dissociation energy for the bond in O2 to calculate a value for the xenon-oxygen bond energy. Give your answer in kJ/mol.

7.1 Solution

$$\Delta H_{rxn} = \Delta H_{deform} - \Delta H_{reform} = 6 \times D(Xe-O) - 3 \times D(O-O)$$

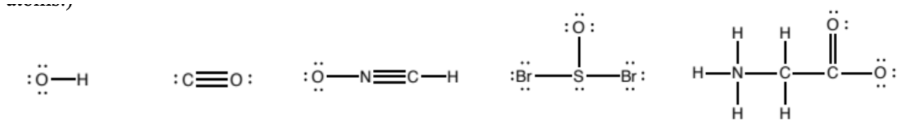
$$6 \times D(Xe-O) = \Delta H + 3 \times D(O-O)$$

$$D(Xe-O) = \frac{\Delta H + 3 \times D(O-O)}{6} = \frac{-804 + 3 \times 142}{6}$$

$$= 71 - 134 = \boxed{-63\,kJ}$$

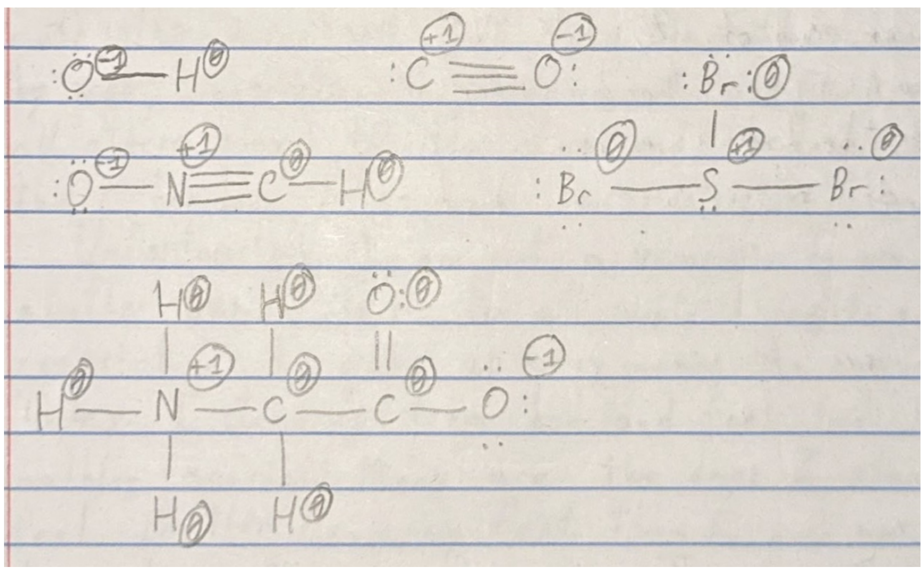
8 Topic F Problem 8

For each of the following molecules, determine the formal charge on each atom. (In your answer, draw the Lewis structure and write all non-zero formal charges next to the corresponding atoms.)



hydroxide ion *carbon monoxide* *fulminic acid* *thionyl bromide* *glycine*

8.1 Solution



9 Topic F Problem 9

There are two resonance structure for the ozone molecule, O_3; these structures are shown below.

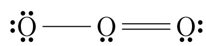


Figure 1: Structure #1

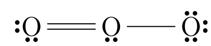


Figure 2: Structure #2

a) A student says "sometimes each bond in O_3 is the same strength as the bond in O=O, and sometimes it's the same strength as the central bond in H-O-O-H." Is this an accurate statement? Explain your answer.

b) Another student says "when O_3 looks like structure #1, the bond on the left is longer than the bond on the right." Is this an accurate statement? Explain your answer.

9.1 Solution

a/ This is not accurate. In truth, the bond strength does not alternate, it stays the same at all times. The difference is that the bond strength is stronger than the H-O-O-H bond but weaker than the O=O bond.

b/ This is not accurate. Firstly, the structure of O_3 does not look like either at any given time. Secondly, the two bonds are identical in both strength and length. If O_3 were to look like structure #1, it would have a longer bond on the left than on the right, but that is not the case and so is the conclusion that arises from it.

10 Topic F Problem 10

This problem asks you to compare two ions: NO_2^+ and NO_2^-. In both of these ions, the nitrogen is the central atom.

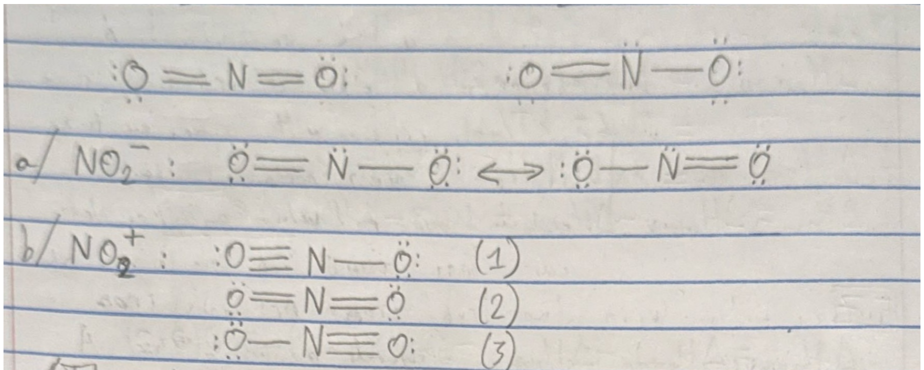
a) One of these ions requires two resonance structures to represent it accurately. Which one is it? Draw the two reasonable resonance structures for this ion.

b) For the other ion, there are three resonance structures that satisfy the octet rule. Draw these three resonance structures for this ion.

c) The ion in part b actually requires just one Lewis structure to depict it accurately. Which structure is this, and why is this the only structure you need?

d) Which are shorter: the nitrogen-oxygen bond distances in NO_2^+, or the nitrogen-oxygen bond distances in NO_2^-? Or do the two ions have equal N–O bond distances? Explain your answer.

10.1 Solution



c/ The only one necessary is the central one (denoted (2) above). It minimizes formal charge for all atoms (sum of magnitudes of 1 compared to 3 and 3). While those of (1) and (3) may exist, they are very uncommon where they are.

d/ The NO_2^+ bonds are shorter. NO_2^+ bonds have a bond order of 2, while NO_2^- bonds are of order 1.5. A higher bond order indicates a stronger and shorter bond.

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