



AP Chemistry 1999 Sample Student Responses

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8. Answer the following questions using principles of chemical bonding and molecular structure.

(a) Consider the carbon dioxide molecule, CO_2 , and the carbonate ion, CO_3^{2-} .

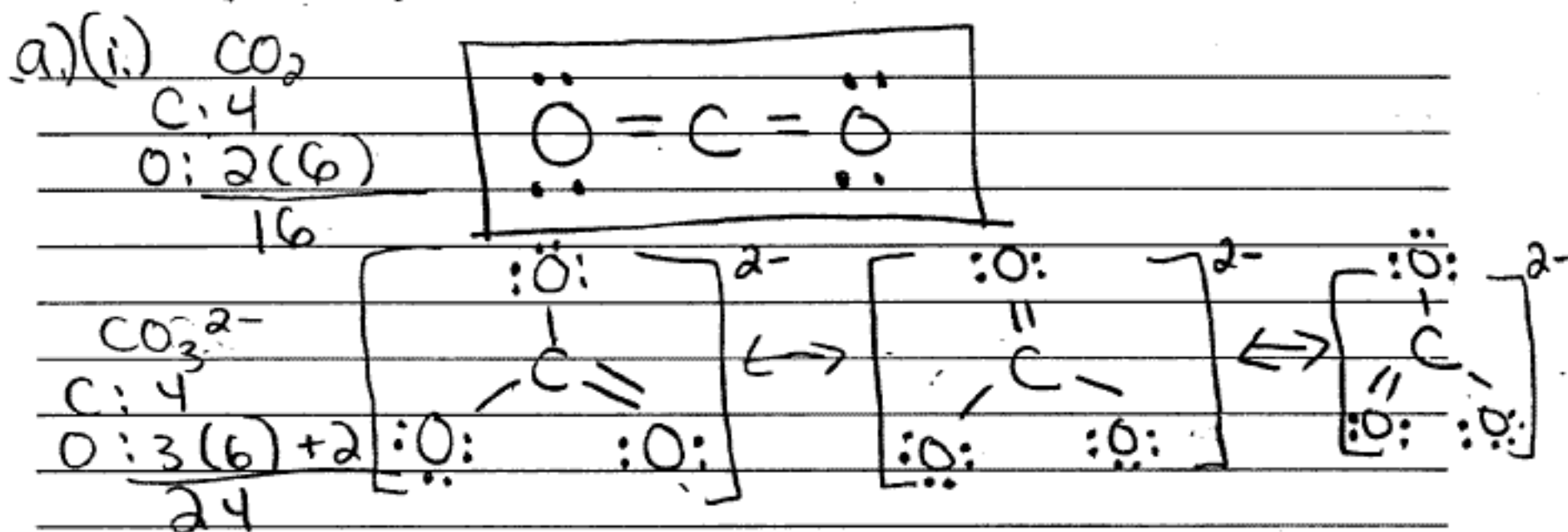
(i) Draw the complete Lewis electron-dot structure for each species.

(ii) Account for the fact that the carbon-oxygen bond length in CO_3^{2-} is greater than the carbon-oxygen bond length in CO_2 .

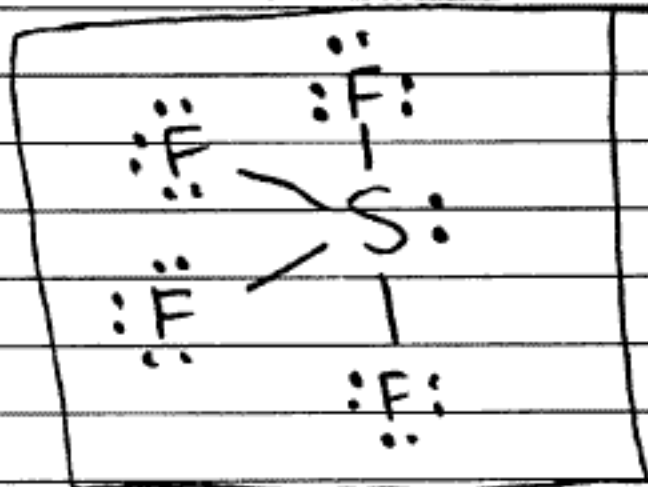
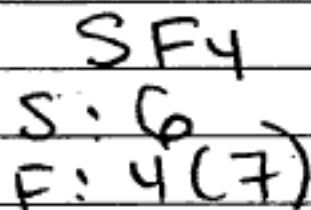
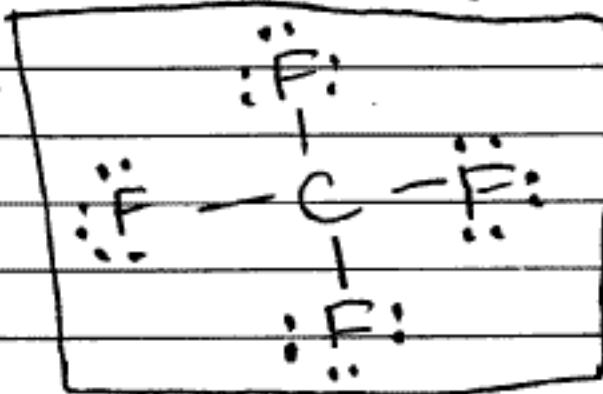
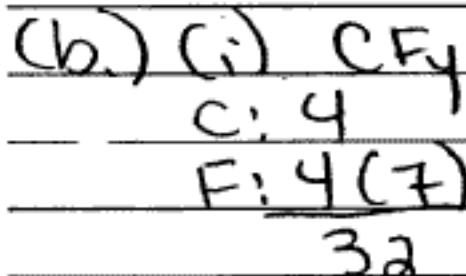
(b) Consider the molecules CF_4 and SF_4 .

(i) Draw the complete Lewis electron-dot structure for each molecule.

(ii) In terms of molecular geometry, account for the fact that the CF_4 molecule is nonpolar, whereas the SF_4 molecule is polar.



(ii) CO_3^{2-} consists of single bonds and double bonds. Since it shows resonance, then the strength of the bonds in CO_3^{2-} is greater than a single bond but smaller than a double bond. CO_2 , however, contains only double bonds and therefore its bonds are stronger than those in CO_3^{2-} . The stronger the bond, the smaller length. Therefore, since CO_3^{2-} contains the weaker bonds, the C-O bond is greater in length than the C-O bond in CO_2 .



(ii) CF_4 is nonpolar because the molecule has a tetrahedral shape. Each Fluorine atom is pulling equally. SF_4 is polar because it has a trigonal bipyramidal shape. Since S has a lone pair electrons, then the molecule has an uneven pull, making the molecule polar.

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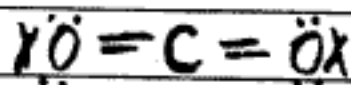
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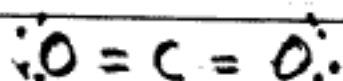
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2) i) CO_2

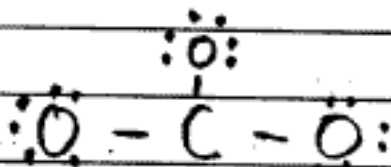


$$4 + 6 \cdot 2 = 16$$

$$= \frac{4}{12}$$



CO_3^{2-}

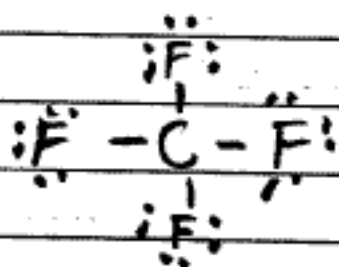


$$4 + 6 \cdot 3 = 22 + 2 = 24$$

$$= \frac{6}{18}$$

ii) CO_2 has 2 double bonds which are shorter than the single bonds of CO_3^{2-}

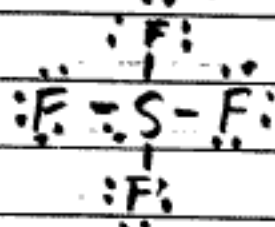
b) i) CF_4



$$4 + 7 \cdot 4 = 32$$

$$= \frac{8}{24}$$

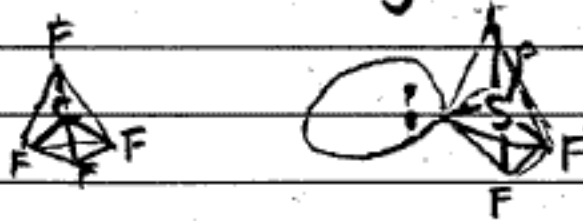
SF_4



$$7 \cdot 4 + 6 = 34$$

$$= \frac{8}{26}$$

ii) CF_4 is Tetrahedral so there are no electron clouds, making it non-polar.



SF_4 is see-saw shaped so the electron cloud is unbalanced, making it polar.

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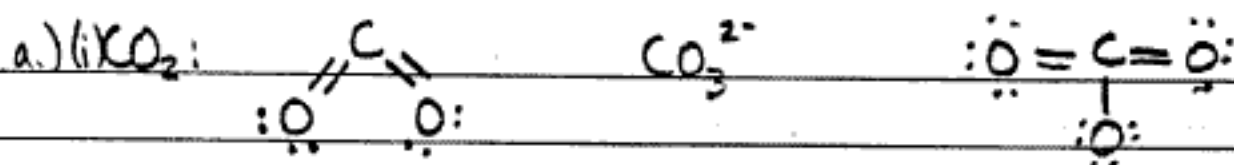
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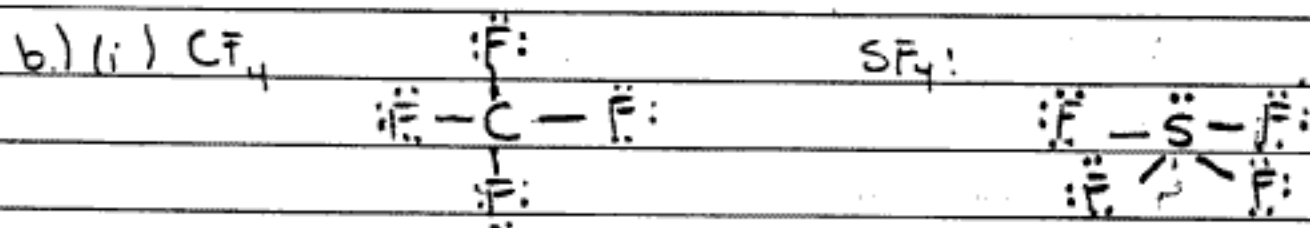
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(ii) In terms of molecular geometry, account for the fact that the CF_4 molecule is nonpolar, whereas the SF_4 molecule is polar.



(ii) In CO_2 all of the carbon-oxygen bonds are double bonds, which are stronger and therefore shorter bonds.



(ii) The CF_4 molecule is in the tetrahedral shape, which means that all of the F molecules are spaced evenly from each other (109° apart). This results in a molecule of uniform charge. In the SF_4 molecule, the S atom is capable of holding 10 valence electrons, and has one pair of free electrons. This deflects the F molecules away, and the result is a square pyramidal molecule, with the free pair of electrons creating a highly negative region, and a highly polar molecule.