AP® Chemistry
2002 Sample Student Responses
Form B

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6. Using principles of chemical bonding and molecular geometry, explain each of the following observations. Lewis electron-dot diagrams and sketches of molecules may be helpful as part of your explanations. For each observation, your answer must include references to both substances.

(a) The bonds in nitrite ion, NO_2^-, are shorter than the bonds in nitrate ion, NO_3^-.

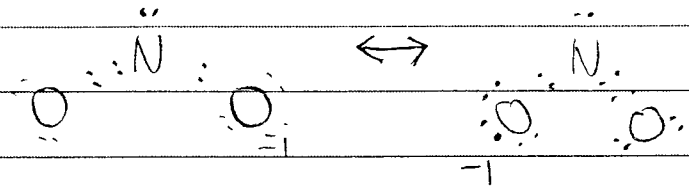
(b) The CH_2F_2 molecule is polar, whereas the CF_4 molecule is not.

(c) The atoms in a C_2H_4 molecule are located in a single plane, whereas those in a C_2H_6 molecule are not.

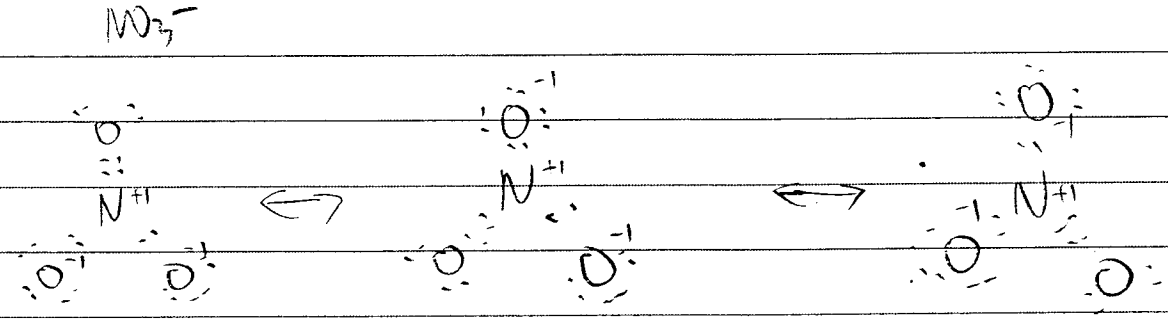
(d) The shape of a PF_5 molecule differs from that of an IF_5 molecule.

(e) $HClO_3$ is a stronger acid than $HClO$.

(a) $5+6\times2+1=18$
$3+8=24$ NO_2^-

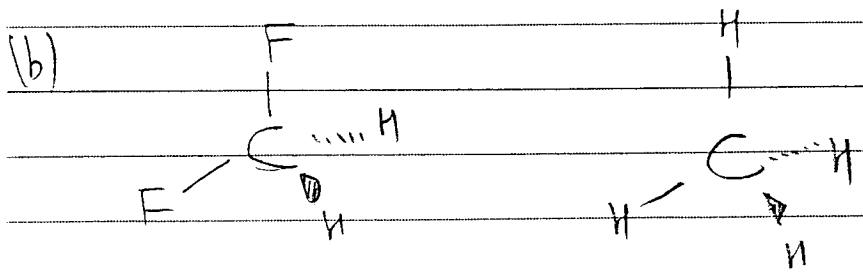


$5+6\times3+1=24$ NO_3^-
$4\times8=32$



The two molecules have structures as shown above. As the resonance structure predicts, the N-O bond in NO_2^- is apparently 1.5, and the N-O bond in NO_3^- is apparently 1.33. Since N-O bond in NO_2^- has greater bond order than that in NO_3^- does, the bonds in NO_2^- are shorter than that in NO_3^-.

(b)

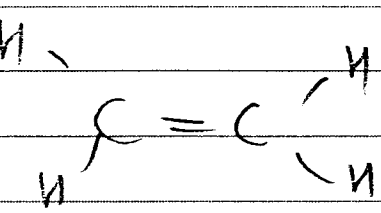


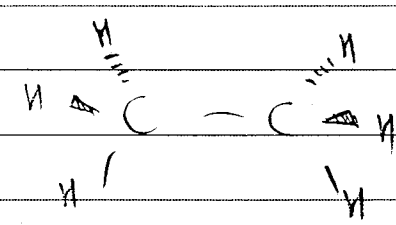
Four bonds in CH_4 are identical, while the bonds in CH_2F_2 are not identical. This asymmetry in structure will make dipole moment, making the molecule polar. The bonds in CH_4 are, however, exactly cancelled to form

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

a nonpolar molecule.

(c)

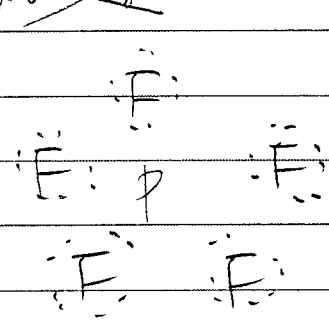




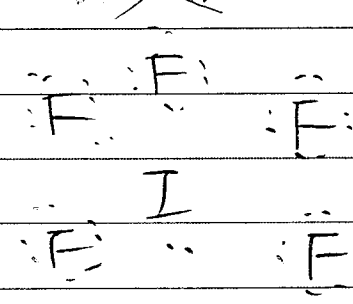
C_2H_4 forms a π-bond, while C_2H_6 does not. If H atom were to rotate with C=C bond its axis, it has to break the π-bond. This cannot happen without a very high temperature, so C_2H_4 is planar. On the other hand, H atom in C_2H_6 are free to rotate, since the geometrical barrier is so small that H atom can overcome it in standard conditions.

(d)

$5+n+5=40$ ~~$8F6=48$~~ PF_5

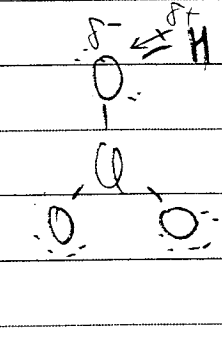


$7+n\times5=42$ ~~$n\times5=42$~~ IF_5

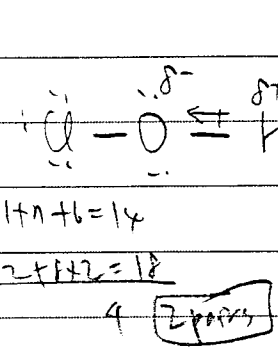


P atom is sp^3d hybridized; F atom is sp^3d^2 hybridized. There is a lone pair in IF_5 molecule. This will distort the structure of IF_5 to form a square planar structure. On the other hand, PF_5 will be trigonal bipyramidal as VSEPR theory predicts.

(e)



$1+n+3\times6=26$
$2+8\times4=34$
8 (4 pairs)



$1+n+6=14$
$2+4+2=18$
4 (2 pairs)

O atom in $HClO_3$ pulls electron more strongly than O atom in HClO does. This is because the other O atoms in $HClO_3$ also pulls electrons toward them. This will cause H atom in $HClO_3$ more "exposed" to surrounding than H atom in HClO, forming $HClO_3$ to be a stronger acid than HClO. This can happen because O atom is electrophilic; i.e. in favor of having electron.

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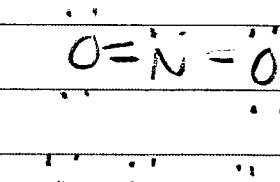
(d) The shape of a PF_5 molecule differs from that of an IF_5 molecule.

(e) $HClO_3$ is a stronger acid than $HClO$.

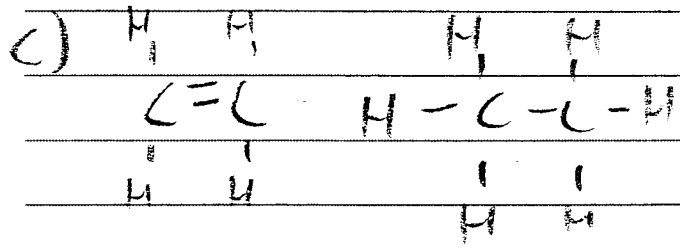
a) $NO_2^- = 5+12+1 = 18$
$NO_3^- = 5+18+1 = 24$

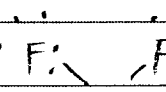


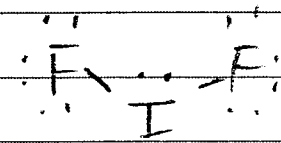
The bond lengths in NO_2^- are in between 1 and 2. The bond length in NO_3^- is abt. in between 1 and 2, but since it has 2 single bonds it's going to be closer to a bond length of one. A double bond is shorter & has a single bond

b) CF_4 is nonpolar because it has a tetrahedral molecular shape, everything cancels out. CH_2F_2 is polar because it has one end that is slightly positive, and one that is slightly negative.

c)

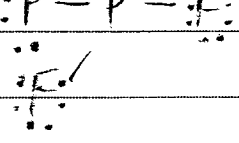


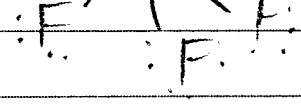




$35+7=42$

d) $7(5)+5=40$





PF_5 has a trigonal bipyramidal shape. IF_5 has unpaired electrons so its molecular shape is a square pyramidal.

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

e) $HClO_3$ is a stronger acid because the difference between the number of H atoms compared to O atoms is 2, whereas for HClO, it's 0