

Chemistry Chapter 6 – Covalent Bonding and Molecular Structure

1. Draw structural formulas for seven different isomers of $C_3H_4Cl_2$

2. (a) Write the ground-state electron configuration for an arsenic atom, showing the number of electrons in each sub shell.

(b) Give one permissible set of four quantum numbers for each of the outermost electrons in a single As atom when it is in its ground state.

(c) Is an isolated arsenic atom in the ground state paramagnetic or diamagnetic? Explain briefly.

(d) Explain how the electron configuration of the arsenic atom in the ground state is consistent with the existence of the following known compounds: Na_3As , $AsCl_3$, and AsF_5 .

ANSWER:

Na_3As - each Na gives up one electron to the As, the As has a complete octet and the sodium atoms are ionically bonded to the arsenic

$AsCl_3$ - the three chlorines each have one half-filled orbital and the arsenic has three. So three covalent bonds are created and the As has one non-bonding pair to make a pyramidal structure.

AsF_5 - fluorine is so electronegative that it draws the two electrons of the non-bonding pair of $AsCl_3$ into bonding. A 4d orbital is involved in the sp^3d hybridization, yielding a trigonal bipyramidal shape.

3. Use simple structure and bonding models to account for each of the following.

(a) The bond length between the two carbon atoms is shorter in C_2H_4 than in C_2H_6 .

(b) The H - N - H bond angle is 107.5° in NH_3 .

(c) The bond lengths in SO_3 are all identical and are shorter than a sulfur-oxygen single bond.

(d) The I_3^- ion is linear.

ANSWER:

a) two points

C_2H_4 has a multiple bond; C_2H_6 has a single bond.

Multiple bonds are stronger and therefore shorter than single bonds.

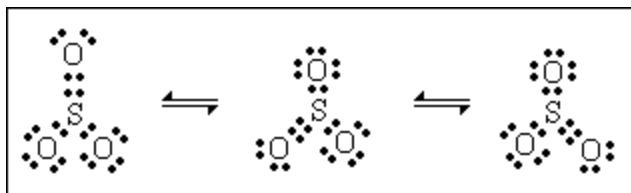
b) two points

NH_3 has 3 bonding pairs and 1 lone pair of electrons.

Bond pairs are forced together because the repulsion between the lone pair and the bond pairs is greater than that between bond pairs.

c) two points

The bonding in SO_3 can be described as a combination of 3 resonance forms of 1 double and single bonds.

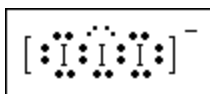


The actual structure is intermediate between the 3 resonance forms, having 3 bonds which are equal and stronger (therefore shorter) than a S-O single bond.

(Credit is given for three sulfur-oxygen double bonds @ 120° with explanation.)

d) two points

The central I atom has 3 lone pairs and 2 bond pairs around it. To minimize repulsion, the 3 lone pairs are arranged in a trigonal plane at right angles to the I-I-I axis.

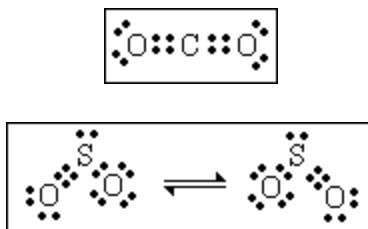


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4. The SO_2 molecule has a dipole moment, whereas the CO_2 molecule has no dipole moment. Include the Lewis (electron-dot) structures in your explanation.

ANSWER:"

b) three points

Lewis structures:



The CO_2 molecule is linear, thus bond dipoles cancel; the SO_2 molecule is bent, resulting in a net dipole.

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- 5) Discuss the polarity of bonds and of molecules. Your discussion might include such topics as dipole moment, dielectric constant, electronegativity, and molecular geometry.
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6. (b) Molecules of AsF_3 are polar, whereas molecules of AsF_5 are nonpolar.

(c) The N-O bonds in the NO_2^- ion are equal in length, whereas they are unequal in HNO_2 .

ANSWERS:

(b) two points

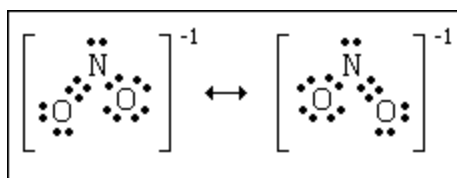
AsF_3 has a trigonal pyramid shape and bond dipoles do NOT cancel (or asymmetric molecule)

AsF_5 has a trigonal bipyramid shape and bond dipoles cancel (or symmetric shape)

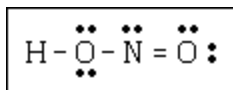
Notes: explanation must refer to shape in order to earn point; one point earned if only correct Lewis structures are given.

(c) two points

NO_2^- has resonance structures



HNO_2 has no resonance structures



OR

one N-O single bond, one N=O double bond

Note: one point earned if only correct Lewis structures, including resonance for NO_2^- given.

7. Cite some of the facts that support the theory of hydrogen bonding.

8.

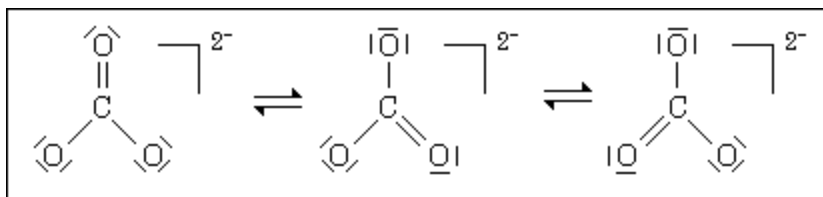
(a) Draw the Lewis electron-dot structures for CO_3^{2-} , CO_2 , and CO , including resonance structures where appropriate.

(b) Which of the three species has the shortest C-O bond length? Explain the reason for your answer.

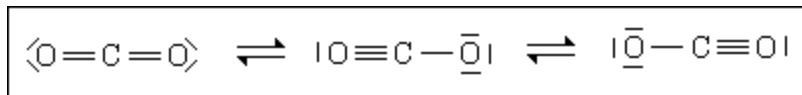
(c) Predict the molecular shapes for the three species. Explain how you arrived at your predictions.

ANSWER

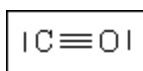
a) 4 points



One point if only one or two structures were given.



Full credit for CO₂ was awarded for giving only the first structure above.



b) 1 point

CO has the shortest bond distance because it has the greatest number of electrons between carbon and oxygen.

c) 3 points

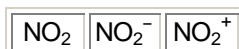
CO₃²⁻ is a trigonal planar. There are 3 bonded pairs of electrons and no lone pairs around C. To minimize the repulsion of the bonded pairs there will be 120° bond angles with all the atoms in the same plane, or C is sp² hybridized with a delocalized pi bond, therefore, CO₃²⁻ must be planar.

CO₂ is linear. It has 2 bonded pairs and no lone pairs of electrons. Or C uses two sp hybridized orbitals.

CO is linear. Two points or atoms make a straight line.

One point was given in part (c) for 3 correct geometrics with no explanations or incorrect or inadequate explanations.

10.



Nitrogen is the central atom in each of the species given above.

(a) Draw the Lewis electron-dot structure for each of the three species.

(b) List the species in order of increasing bond angle. Justify your answer.

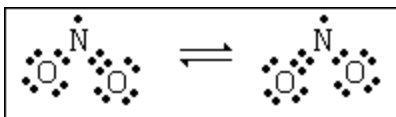
(c) Select one of the species and give the hybridization of the nitrogen atom in it.

ANSWER:

9) average score = 2.5

a) three points; one point per structure; minus one point for one or more missing charges.

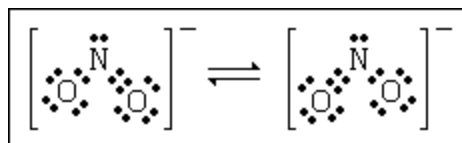
NO₂



A correct structure with one electron on oxygen is OK.

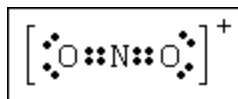
Note added to standards: Although not required by the wording of the question, both resonance forms are shown.

NO₂⁻



Note added to standards: Although not required by the wording of the question, both resonance forms are shown.

NO₂⁺

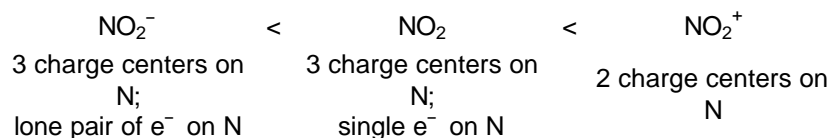


b) three points

NO₂⁻ < NO₂ < NO₂⁺

[This order, whether or not structures are drawn in (a) are correct, receives one point. If structures in (a) are incorrect, an order that is consistent with the structures actually given in (a) receives one point.]

Whether structures in (a) are correct or incorrect, one point is awarded for any one correct angle or ranking consistent with a particular structure, with appropriate justification; two points are awarded for two correct comparisons with justifications; for the correct order:



c) one point

Hybridization:

NO₂⁺ is sp

NO₂ is sp²

NO₂⁻ is sp² also.

11. 5) Consider the molecules PF_3 and PF_5 .

a) Draw the Lewis electron-dot structures for PF_3 and PF_5 and predict the molecular geometry of each.

b) Is the PF_3 molecular polar, or is it nonpolar? Explain.

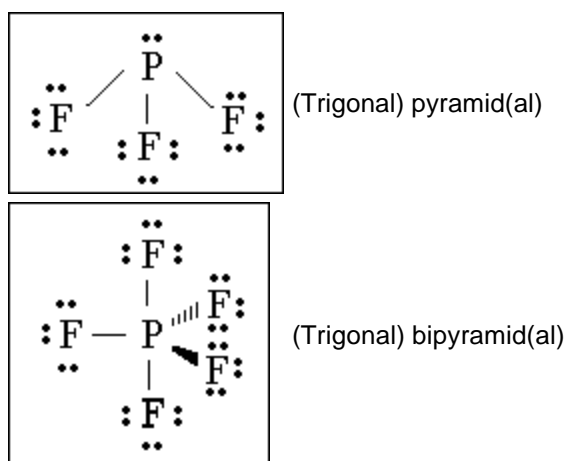
c) On the basis of bonding principles, predict whether each of the following compounds exists. In each case, explain your prediction.

(i) NF_5

(ii) AsF_5

ANSWER:

5)



1 point for each structure

Note ; One point (total) deducted if lone pairs not shown on F atoms in either molecule.

(b) The PF_3 molecule is polar

The three P-F dipoles do not cancel, or,

the lone pair on P leads to asymmetrical distribution of charge.

Note; "Molecule is not symmetrical" does not earn point. Both points can be earned if answer is consistent with incorrect (a).

(c) NF_5 does not exist because no 2d orbitals exist for use in bonding, or,

N is too small to accommodate 5 bonding pairs

AsF_5 does exist because 4d orbitals are available for use in bonding, or,

As can accommodate an expanded octet using d orbitals

Note; Response with two correct predictions with no explanations earns one point. Also, argument of "no expanded octet" vs. "expanded octet" alone does not earn explanation point.

12. The chemical properties of an element are determined by the electron configuration. For the elements barium, fluorine, manganese, boron, and neon, cite evidence which illustrates this statement and show how the evidence supports the statement.

13. Draw Lewis structures for CO_2 , H_2S , SO_3 , and SO_3^{2-} and predict the shape of each species.

14

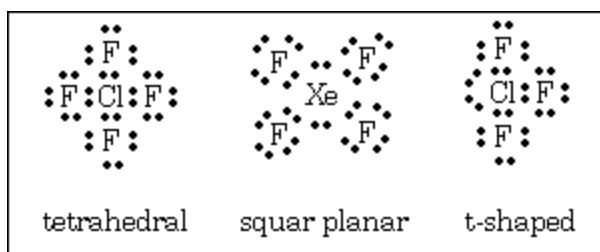


(a) Draw a Lewis electron-dot structure for each of the molecules above and identify the shape of each.

(b) Use the valence shell electron-pair repulsion (VSEPR) model to explain the geometry of each of these molecules.

ANSWER:

a) 1 point for each correct diagram, 1 point for any two structure names, 1 more point for all three structure names.



b) three points. A maximum of 1 point was deducted if repulsion of atoms rather than of electron pairs was mentioned.

CF_4 - 4 bonding pairs around the C at corners of regular tetrahedron to minimize repulsion (maximize bond angles).

XeF_4 - 4 bonding pairs and 2 lone pairs give octahedral shape with lone pairs on opposite sides of Xe atoms.

ClF_3 - 3 bonding pairs and 2 lone pairs give trigonal bipyramid with lone pairs in equatorial positions 120° apart.

15.