Question No. 1 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

1. Lewis structure is used to model covalent bonds of a molecule or ion. Covalent bonds are a type of chemical bonding formed by the sharing of electrons in the valence shells of the atoms. Most bonding is not purely covalent, but is polar covalent (unequal sharing) based on electronegativity differences. H_2S is a polar covalent molecule. In its Lewis structure, the central atom sulfur has ___.

(A) 1 bonding pair
(B) 1 bonding pair and 1 lone pair
(C) 2 bonding pairs
(D) 2 bonding pairs and 1 lone pair
(E) 2 bonding pairs and 2 lone pairs

Feedback

A. Incorrect.

The sulfur atom is bonded to two hydrogen atoms. There are two bonding pairs.

B. Incorrect.

The sulfur atom is bonded to two hydrogen atoms.

C. Incorrect.

Two bonding pairs alone would not give sulfur a full valence shell.

D. Incorrect.

Two bonding pairs and 1 lone pair would not give sulfur a full valence shell.

E. Correct.

Good job! Two bonding pairs and two lone pairs give the sulfur atom a full valence shell.

Solution

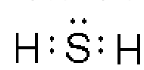
Arrange the atoms.

H S H

Determine number of valence electrons.

H = 1
S = 6

Place valence electrons around each atom.



S has 8 and each H has 2—valences are now full.

There are 2 bonding pairs and 2 lone pairs around the sulfur atom.

The correct answer is (E).

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

2. A simple idea to understand chemistry is that chemistry is the consequence of all elements trying to achieve the noble gas configuration. This can be accomplished by reacting with one another to gain, lose or share electrons so that each atom ends up with 8 electrons in their outer shell. This basically is the Octet rule. Using this rule, the most likely ion to be formed by phosphorus is ___.

(A) P^{5-}
(B) P^{-}
(C) P^{3-}
(D) P^{3+}
(E) P^{5+}

Feedback

A. Incorrect.

Phosphorus has 5 valence electrons. The most it can gain is 3 electrons in order to reach 8 – a noble-gas configuration. This is not a likely ion.

B. Incorrect.

Phosphorus has 5 valence electrons. There are 6 electrons after gaining one electron (P^{-}). This is not an octet configuration.

C. Correct.

Good job! Phosphorus has 5 valence electrons. Due to its electronegativity, it is more likely to gain electrons than lose them. Adding 3 additional electrons reaches the octet to make P^{3-}.

D. Incorrect.

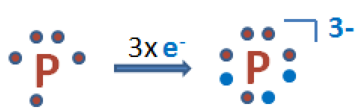
Phosphorus has 5 valence electrons. There are still 2 electrons left after losing 3 electrons (P^{3+}). This is not an octet configuration.

E. Incorrect!
Phosphorus has 5 valence electrons. It is easier to gain 3 electrons to reach the noble gas configuration than to lose 5 electrons.

Solution

Phosphorus has an electron configuration of [Ne]$3s^2 3p^3$. There are 5 valence electrons. To reach the noble-gas configuration of Ar = [Ne]$3s^2 3p^6$, it needs three additional electrons. To gain electrons, the species becomes negatively charged ion (anion).

$P + 3e^{-} \rightarrow P^{3-}$



Now it has a full valence shell of 8.

You might ask why can phosphorus loses 5 electrons to become P^{5+} instead, i.e. a noble-gas configuration of [Ne]. The simple answer is on its electronegativity. Phosphorus is a nonmetal with 2.18 electronegativity value. It is much likely to gain electrons than to lose electrons with this magnitude of electronegativity (electron-loving).

The correct answer is (C).

Question No. 3 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

3. Organic chemistry is mainly the chemistry of carbon compounds. Due to the tetravalent nature, carbon can form many bond types with another carbon or other nonmetals. Carbon-hydrogen bond is always a single bond. Chloroethene (C_2H_3Cl) is also commonly called vinyl chloride. It is the monomer to produce polymer polyvinyl chloride (PVC). In its Lewis structure, C_2H_3Cl contains ____.

(A) 1 double bond
(B) 2 double bonds
(C) 1 triple bond
(D) 2 triple bonds
(E) All single bonds

Feedback

A. Correct.

Good job! All atoms are added up to 18 valence electrons. Draw the Lewis structure according to the Octet rule and double up as needed. Count the bond types.

B. Incorrect.

All atoms are added up to 18 valence electrons. Draw the Lewis structure according to the Octet rule and double up as needed. Count the bond types.

C. Incorrect.

All atoms are added up to 18 valence electrons. Draw the Lewis structure according to the Octet rule and double up as needed. Count the bond types.

D. Incorrect.

All atoms are added up to 18 valence electrons. Draw the Lewis structure according to the Octet rule and double up as needed. Count the bond types.

E. Incorrect.

All atoms are added up to 18 valence electrons. Draw the Lewis structure according to the Octet rule and double up as needed. Count the bond types.

Solution

Arrange the atoms.

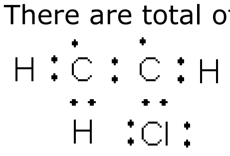
H C C H

H Cl

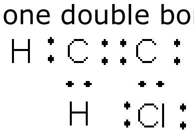
Determine valence electrons.

C = 2x4 = 8
H = 3x1 = 3
Cl = 7

There are total of 18 valence electrons. Place electrons around atoms.



The two carbons do not have full valence shells. Double up on them. There is only one double bond in this structure.



The correct answer is (A).

Question No. 4 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

4. A resonance structure is an alternative way of drawing a Lewis structure, yet it still satisfies the rules. Draw the Lewis structure(s) of NO_2F. The central atom N has ___ unshared electron pair(s).

(A) 2
(B) 1
(C) 0
(D) 3
(E) 4

Feedback

A. Incorrect.

Count the total number of valence electrons and draw them all. Double up as needed to form a double bond. Check the Octet rule on each.

B. Incorrect.

Count the total number of valence electrons and draw them all. Double up as needed to form a double bond. Check the Octet rule on each.

C. Correct.

Good job! Count the total number of valence electrons and draw them all. Double up as needed to form a double bond. Check the Octet rule on each.

D. Incorrect.

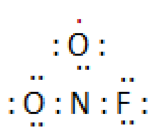
Count the total number of valence electrons and draw them all. Double up as needed to form a double bond. Check the Octet rule on each.

E. Incorrect!
Count the total number of valence electrons and draw them all. Double up as needed to form a double bond. Check the Octet rule on each.

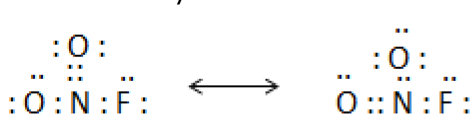
Solution

The concept of resonance structures is important in understanding the electronic structures of electron-rich molecules, such as multiple bonds and radicals (odd number of valence electrons in a molecule). For some molecules with identical atoms, there are multiple ways to draw a Lewis structure. Watch this example.

First count the total number of valence electrons: 1xN (5) + 2xO (2x6) + 1xF(7) = $24e^-$. Set N as a central atom and the rest as surrounding atoms.



This arrangement has 26 e^-, too many! It's time to double up. Since we have two identical O atoms, we can double up either the 1st oxygen or the 2nd oxygen. This results in two slightly different Lewis structures which both represent the same molecule. They are called resonance structures and both have 24 e^-.



Both structures have no lone pairs on N.

The correct answer is (C).

Question No. 5 of 10

<table>
<tr><td colspan="2">Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.</td></tr>
<tr><td>
Question</td><td>5. Due to the electron configuration of fluorine ([He]$2s^2 2p^5$), it does not form a double bond with any element. There are 7 electrons in outermost shell and it takes only one more to complete the octet. In which of the compounds is the Octet rule violated by the central atom in its Lewis structure?

(A) ClF
(B) OF_2
(C) ClF_3
(D) PF_3
(E) SiF_4</td></tr>
<tr><td rowspan="5">
Feedback</td><td>A. Incorrect.

This molecule can have the Lewis structure to meet the Octet rule.</td></tr>
<tr><td>B. Incorrect.

This molecule can have the Lewis structure to meet the Octet rule.</td></tr>
<tr><td>C. Correct.

Good job! In ClF_3, the central atom would have 10 valence electrons, not 8. Cl-F does not form a double bond.</td></tr>
<tr><td>D. Incorrect.

This molecule can have the Lewis structure to meet the Octet rule.</td></tr>
<tr><td>E. Incorrect!
This molecule can have the Lewis structure to meet the Octet rule.</td></tr>
<tr><td>
Solution</td><td>In ClF_3, the central atom would have 10 valence electrons, not 8. Cl-F does not form a double bond. Its structure violets the Octet rule.

The rest of molecules can have the Lewis structures in compliance of the Octet rule where the central atoms have 8 valence electrons.

The correct answer is (C).</td></tr>
</table>

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

6. For which of the molecules is the molecular geometry (shape) the same as electronic geometry?
(i) PCl_3 (ii) CCl_4 (iii) $TeCl_4$ (iv) XeF_4 (v) SCl_6

(A) (i) and (iii)
(B) (i) and (iv)
(C) (ii) and (v)
(D) (ii) only
(E) (v) only

Feedback

A. Incorrect.

Draw out the Lewis structures for five molecules and determine the electronic structures by counting the electron regions. If there is no lone pair left in the central atom, their molecular and electronic geometry are identical according to VSEPR.

B. Incorrect.

Draw out the Lewis structures for five molecules and determine the electronic structures by counting the electron regions. If there is no lone pair left in the central atom, their molecular and electronic geometry are identical according to VSEPR.

C. Correct.

Good job! Draw out the Lewis structures for five molecules and determine the electronic structures by counting the electron regions. If there is no lone pair left in the central atom, their molecular and electronic geometry are identical according to VSEPR.

D. Incorrect.

Draw out the Lewis structures for five molecules and determine the electronic structures by counting the electron regions. If there is no lone pair left in the central atom, their molecular and electronic geometry are identical according to VSEPR.

E. Incorrect.

Draw out the Lewis structures for five molecules and determine the electronic structures by counting the electron regions. If there is no lone pair left in the central atom, their molecular and electronic geometry are identical according to VSEPR.

Solution

Follow the four-step process in determining the molecular geometry: (1) Write out the Lewis structure; (2) Count the total electron regions; (3) Determine the electronic geometry based on the electron region total; (4) Determine the molecular geometry by ignoring any lone pair(s) at the central atom.

(i) PCl_3: Electronic Geometry = Tetrahedral; Molecular Geometry = Trigonal Pyramidal.
(ii) CCl_4: Electronic Geometry = Tetrahedral; Molecular Geometry = Tetrahedral
(iii) $TeCl_4$: Electronic Geometry = Trigonal Bipyramidal; Molecular Geometry = See-Saw.
(iv) XeF_4: Electronic Geometry = Octahedral; Molecular Geometry = Square Planar
(v) SCl_6: Electronic Geometry = Octahedral; Molecular Geometry = Octahedral

The correct answer is (C).

Question No. 7 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

7. Carbonate ion is a polyatomic anion in limestone as calcium carbonate. Sodium bicarbonate is the key ingredient of baking soda. What is the VSEPR molecular geometry for CO_3^{2-}?

(A) Trigonal Planar
(B) Trigonal Pyramidal
(C) Tetrahedral
(D) Bent
(E) Linear

Feedback

A. Correct.

Good job! There are three bonding regions and no lone pairs in the Lewis structure. It is trigonal planar geometry.

B. Incorrect.

This molecule has 3 bonding regions and no lone pairs. It is not trigonal pyramidal.

C. Incorrect.

This molecule has 3 bonding regions and no lone pairs. It is not tetrahedral.

D. Incorrect.

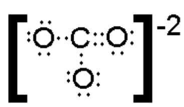
This molecule has 3 bonding regions and no lone pairs. It is not bent.

E. Incorrect.

This molecule has 3 bonding regions and no lone pairs. It is not linear.

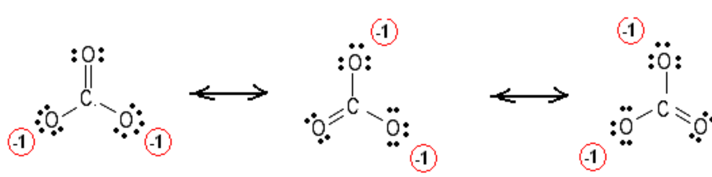
Solution

CO_3^{2-} has three bonding regions and no lone pair regions. This is trigonal planar shape.



Some molecules involve two or more structures that are equivalent. Resonance represents the multiple forms that a molecule can exist.

Because of three identical oxygen atoms, CO_3^{2-} has three alternative forms (resonance structures) to represent the overall electronic structure.



The correct answer is (A).

Question No. 8 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

8. The VSEPR model does a good job of predicting molecule geometry, based on electron regions and all-important idea of electron pair repulsion. Lone pairs tend to take up more space than bonding pairs. Apply this idea, which has a larger Cl-P-Cl bond angle, PCl_3 or PCl_4^+?

(A) PCl_3
(B) PCl_4^+
(C) They are both the same.
(D) Cannot be determined from the given information.
(E) None of the above

Feedback

A. Incorrect.

PCl_3 has a lone pair while the ion PCl_4^+ does not. The lone pair on PCl_3 takes up more space and pushes the P-Cl bonds closer. Its Cl-P-Cl (100°) is therefore less than the tetrahedron's 109.5°.

B. Correct!

PCl_3 has a lone pair while the ion PCl_4^+ does not. PCl_4^+ has the tetrahedral geometry with no lone pair on the central atom. The Cl-P-Cl is 109.5°.

C. Incorrect.

PCl_3 has a lone pair while the ion does not. Their bond angles are not the same.

D. Incorrect.

PCl_3 has a lone pair while the ion does not. There is sufficient information given.

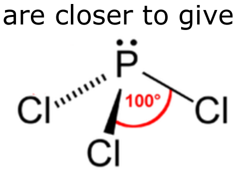
E. Incorrect.

There is one correct answer above.

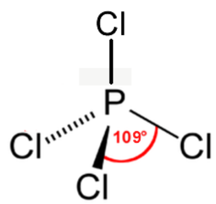
Solution

They both have 4 electron regions. PCl_3 has 1 lone pair while PCl_4^+ has none. Lone pairs distort bond angles and push toward each other. Therefore PCl_4^+, with no lone pair on P, has a larger bond angle.

PCl_3 has the trigonal pyramidal geometry. Due to the lone pair on P, the P-Cl bonds are closer to give more space for the lone pair. The bond angle is about 100°.



PCl_4^+ has the tetrahedral geometry with no lone pair on the central atom. The bond angle is expected to be a perfect 109.5°.



The correct answer is (B).

Question No. 9 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

9. A simple model of VSEPR can predict the molecular geometry and in turn the polarity of a molecule. Symmetry of a molecule determines its polarity. Which molecular geometry always results in polar molecules?

(A) Tetrahedral
(B) Trigonal Bipyramidal
(C) Trigonal Pyramidal
(D) Octahedral
(E) Linear

Feedback

A. Incorrect.

Although all of them can produce polar molecules, one of them has a lone pair of electrons that always results in a net dipole. Tetrahedron has the symmetry to cancel all bond polarities out, resulting in net dipole of zero.

B. Incorrect.

Although all of them can produce polar molecules, one of them has a lone pair of electrons that always results in a net dipole. Trigonal bipyramidal has the symmetry to cancel all bond polarities out, resulting in net dipole of zero.

C. Correct.

Good job! Although all of them can produce polar molecules, trigonal pyramidal has a lone pair of electrons that always results in a net dipole for the molecule.

D. Incorrect.

Although all of them can produce polar molecules, one of them has a lone pair of electrons that always results in a net dipole. Octahedron has the symmetry to cancel all bond polarities out, resulting in net dipole of zero.

E. Incorrect.

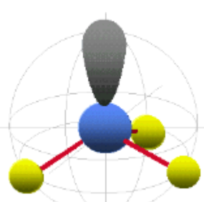
Although all of them can produce polar molecules, one of them has a lone pair of electrons that always results in a net dipole. Some linear molecules have the symmetry to cancel all bond polarities out, resulting in net dipole of zero.

Solution

To determine the molecular polarity:

(1) Draw out the Lewis structure;
(2) Assign the polarity of each bond;
(3) Apply the symmetry and see if the bond dipoles have any net molecular dipole. Highly symmetrical molecules tend to have zero molecular polarity since their bond polarities can all cancel out.

Although all of them can produce polar molecules, trigonal pyramidal has a lone pair of electrons that always results in a net dipole for the molecule.



The correct answer is (C).

Question No. 10 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

10. To determine the Lewis structure, count the valence electrons. To determine the geometry, count the total electron regions. Which one of the following molecules has tetrahedral molecular geometry?

(A) CF_4
(B) XeF_4
(C) SCl_4
(D) IF_4^-
(E) C_2H_2

Feedback

A. Correct.

Good job! Draw out the Lewis structure and count the electron regions. Determine the electronic geometry based on the electron region total. Ignore any lone pair on the central atom and determine the molecular geometry. Adjust the bond angle to give away more space for lone pairs. ClF_4 has the same molecular geometry as its electronic geometry since there is no lone pair left on the central atom.

B. Incorrect.

Draw out the Lewis structure and count the electron regions. Determine the electronic geometry based on the electron region total. Ignore any lone pair on the central atom and determine the molecular geometry. Adjust the bond angle to give away more space for lone pairs. XeF_4 has trigonal planar molecular geometry with two lone pairs on Xe.

C. Incorrect.

Draw out the Lewis structure and count the electron regions. Determine the electronic geometry based on the electron region total. Ignore any lone pair on the central atom and determine the molecular geometry. Adjust the bond angle to give away more space for lone pairs. SCl_4 has see-saw shape with one lone pair at the equatorial position.

D. Incorrect.

Draw out the Lewis structure and count the electron regions. Determine the electronic geometry based on the electron region total. Ignore any lone pair on the central atom and determine the molecular geometry. Adjust the bond angle to give away more space for lone pairs. IF_4^- has the square planar geometry with two lone pairs.

E. Incorrect.

Draw out the Lewis structure and count the electron regions. Determine the electronic geometry based on the electron region total. Ignore any lone pair on the central atom and determine the molecular geometry. Adjust the bond angle to give away more space for lone pairs. C_2H_2 has the linear geometry with carbon-carbon triple bond.

Solution

CF_4 has the tetrahedral molecular geometry like methane.
XeF_4 has trigonal planar molecular geometry with two lone pairs on Xe.
SCl_4 has see-saw shape with one lone pair at the equatorial position.
IF_4^- has the square planar geometry with two lone pairs.
C_2H_2 has the linear geometry with carbon-carbon triple bond.

The correct answer is (A).