

## Predicting the Shape of a Molecule (Student textbook page 236)

11. What molecular shape is represented by each of the following VSEPR notations?

- a.  $AX_3$
- b.  $AX_5E$

### What Is Required?

You need to assign a molecular shape that is represented by two VSEPR notations.

### What Is Given?

You are given the VSEPR notations:

- a.  $AX_3$
- b.  $AX_5E$

a.  $AX_3$

Plan Your Strategy	Act on Your Strategy
Determine what types of groups and how many of each type are present in the molecule.	There is a central atom and three surrounding atoms but no lone pairs in the molecule.
Apply the principles of electron repulsion to the groups to determine the shape.	Bonding pairs repel equally so the three surrounding atoms will be as far from each other as possible. This would place them at the corners of a triangle with the central atom in the centre. This molecular shape is trigonal planar.

b.  $AX_5E$

Plan Your Strategy	Act on Your Strategy
Determine what types of groups and how many of each group are present.	There is a central atom, five surrounding atoms, and one lone pairs in the molecule.
Apply the principles of electron repulsion to the groups to determine the shape.	The six electron groupings will repel one another but the lone pair will repel more than the others. The electron groupings will be approximately at the corners of an octahedron. The lone pair will not be part of the molecular shape leaving four of the surrounding atoms at the corners of a square and the fifth at the centre and above the square. The central atom will be in the centre of the square. This molecular shape is square pyramidal.

### Check Your Solution

A comparison with the figures in Figure 4.31 on page 234 of the student textbook confirms the results.

12. What is the total number of valence electrons surrounding each of the atoms in the following compounds?

- a.  $\text{CF}_4(\text{g})$
- b.  $\text{NO}_3^-(\text{s})$

### What Is Required?

You need to determine the total number of valence electrons associated with each of the atoms in two compounds.

### What Is Given?

You are given the compounds:

- a.  $\text{CF}_4(\text{g})$
- b.  $\text{NO}_3^-(\text{s})$

a.  $\text{CF}_4(\text{g})$

Plan Your Strategy	Act on Your Strategy
Draw a Lewis structure of the compound.	$  \begin{array}{c}  :\ddot{\text{F}}: \\    \\  :\ddot{\text{F}}-\text{C}-\ddot{\text{F}}: \\    \\  :\ddot{\text{F}}:  \end{array}  $
Count the number of electrons surrounding each atom.	There are eight valence electrons around each of the atoms, giving a total of 32 valence electrons in the compound.

b.  $\text{NO}_3^-(\text{s})$

Plan Your Strategy	Act on Your Strategy
Draw a Lewis structure of the compound.	$  \left[ \begin{array}{c} :\ddot{\text{O}}: \\    \\ :\ddot{\text{O}}-\text{N}-\ddot{\text{O}}: \\   \\ :\ddot{\text{O}}: \end{array} \right]^- \leftrightarrow \left[ \begin{array}{c} :\ddot{\text{O}}: \\   \\ :\ddot{\text{O}}=\text{N}-\ddot{\text{O}}: \\   \\ :\ddot{\text{O}}: \end{array} \right]^- \leftrightarrow \left[ \begin{array}{c} :\ddot{\text{O}}: \\   \\ :\ddot{\text{O}}-\text{N}=\ddot{\text{O}}: \\   \\ :\ddot{\text{O}}: \end{array} \right]^-  $
Count the number of electrons surrounding each atom.	In all of the three resonance structures, there are eight valence electrons around each of the atoms giving a total of 24 valence electrons in the compound.

### Check Your Solution

Each atom in both compounds has an octet of valence electrons which creates stability.

13. How many lone pairs and electron groups are associated with the central atom of the following molecules and ions? Remember that double and triple bonds count as only one electron group for the purpose of predicting molecular shape.
- $\text{NH}_4^+(\text{s})$
  - $\text{HCN}(\text{g})$
  - $\text{XeF}_4(\text{s})$
  - $\text{PbCl}_2(\text{vaporized})$

### What Is Required?

You need to determine the number of electron groups around the central atom of four compounds.

### What Is Given?

You are given the chemical formulas:

- $\text{NH}_4^+(\text{s})$
- $\text{HCN}(\text{g})$
- $\text{XeF}_4(\text{s})$
- $\text{PbCl}_2(\text{vaporized})$

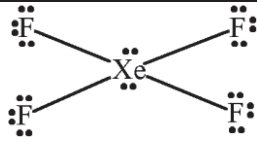
#### a. $\text{NH}_4^+(\text{s})$

Plan Your Strategy	Act on Your Strategy
Draw the Lewis structure.	$\left[ \begin{array}{c} \text{H} \\   \\ \text{H}-\text{N}-\text{H} \\   \\ \text{H} \end{array} \right]^+$
Count the number of each type of electron group around the central atom.	4 BP, 0 LP

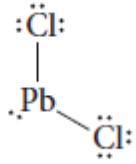
#### b. $\text{HCN}(\text{g})$

Plan Your Strategy	Act on Your Strategy
Draw the Lewis structure.	$\text{H}-\text{C}\equiv\text{N:}$
Count the number of each type of electron group around the central atom.	2 BP, 0 LP

#### c. $\text{XeF}_4(\text{s})$

Plan Your Strategy	Act on Your Strategy
Draw the Lewis structure.  (This structure cannot be obtained by basic steps and requires research. The Xe hybridization is $sp^3s^2$ .)	
Count the number of each type of electron group around the central atom.	4 BP, 2 LP

d.  $\text{PbCl}_2$ (vaporized)

Plan Your Strategy	Act on Your Strategy
Draw the Lewis structure.  (This structure cannot be obtained by basic steps and requires research.)	
Count the number of each type of electron group around the central atom.	2 BP, 1 LP

**Check Your Solution**

The rules have been followed and the answers are reasonable.

14. Use VSEPR theory to predict the shape of  $\text{O}_3(\text{g})$ .

**What Is Required?**

You need to predict the shape of ozone,  $\text{O}_3(\text{g})$ .

**What Is Given?**

The chemical formula shows that the molecule consists of three oxygen atoms.

Plan Your Strategy	Act on Your Strategy
Draw the Lewis structure based on the principles for drawing Lewis structures.	$\text{:}\ddot{\text{O}}\text{—}\ddot{\text{O}}\text{=}\ddot{\text{O}}\text{:} \longleftrightarrow \text{:}\ddot{\text{O}}\text{=}\ddot{\text{O}}\text{—}\ddot{\text{O}}\text{:}$
Count the electron groups around the central atom and account for any charge if the compound is an ion.	In either of the resonance forms, there are three electron groups around the central oxygen atom. There is no charge.
Find the name of the electron group arrangement.	This electron group arrangement is called trigonal planar.
Predict the molecular shape based on the location of the bonding pairs and lone pairs in the electron groups.	There are two bonding pairs and one lone pair. This arrangement forms the molecular shape called <u>bent</u> . The bond angle is expected to be less than $120^\circ$ .

**Check Your Solution**

This arrangement fits the VSEPR notation  $\text{AX}_2\text{E}$  which represents the bent molecular shape.

15. Use VSEPR theory to predict the shape of  $\text{PH}_3(\text{g})$ .

**What Is Required?**

You need to predict the molecular shape of phosphorus trihydride,  $\text{PH}_3(\text{g})$ .

**What Is Given?**

The chemical formula shows that the molecule consists of one phosphorus atom and three hydrogen atoms.

Plan Your Strategy	Act on Your Strategy
Draw the Lewis structure based on the principles for drawing Lewis structures.	$\begin{array}{c} \text{H} - \ddot{\text{P}} - \text{H} \\   \\ \text{H} \end{array}$
Count the electron groups around the central atom and account for any charge if the compound is an ion.	There are four electron groups around the central phosphorus atom. There is no charge.
Find the name of the electron group arrangement.	This electron group arrangement is called tetrahedral.
Predict the molecular shape based on the location of the bonding pairs and lone pairs in the electron groups.	There are three bonding pairs and one lone pair. This arrangement forms the molecular shape called <u>trigonal pyramidal</u> . The bond angle is expected to be less than $109.5^\circ$ .

**Check Your Solution**

This arrangement fits the VSEPR notation  $\text{AX}_3\text{E}$  which represents the trigonal pyramidal molecular shape.

16. Use VSEPR theory to predict the shape of  $\text{SO}_4^{2-}(\text{s})$ .

**What Is Required?**

You need to predict the shape of the sulfate ion.

**What Is Given?**

You are given the chemical formula,  $\text{SO}_4^{2-}(\text{s})$ .

Plan Your Strategy	Act on Your Strategy
<p>Draw the Lewis structure based on the principles for drawing Lewis structures.</p> <p>There are six resonance structures for the sulfate ion. They all contain an expanded valence.</p>	
Count the electron groups around the central atom and account for any charge if the compound is an ion.	In each of the resonance structures, there are four electron groups around the central sulfur atom. The ion has a charge of 2-.
Find the name of the electron group arrangement.	This electron group arrangement is called tetrahedral.
Predict the molecular shape based on the location of the bonding pairs and lone pairs in the electron groups.	There are four bonding pairs and no lone pairs. This arrangement forms the molecular shape called <u>tetrahedral</u> . The bond angle is expected to be $109.5^\circ$ .

**Check Your Solution**

This arrangement fits the VSEPR notation  $\text{AX}_4$  which represents the tetrahedral molecular shape.

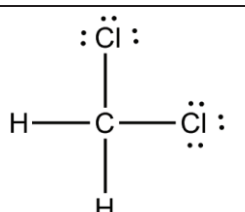
17. Use VSEPR theory to predict the shape and bond angles of  $\text{CH}_2\text{Cl}_2(\ell)$ .

**What Is Required?**

You need to predict the shape of dichloromethane.

**What Is Given?**

You are given the formula,  $\text{CH}_2\text{Cl}_2(\ell)$ .

Plan Your Strategy	Act on Your Strategy
Draw the Lewis structure based on the principles for drawing Lewis structures.	
Count the electron groups around the central atom and account for any charge if the compound is an ion.	There are four electron groups around the central carbon atom. There is no charge.
Find the name of the electron group arrangement.	This electron group arrangement is called tetrahedral.
Predict the molecular shape based on the location of the bonding pairs and lone pairs in the electron groups.	There are four bonding pairs and no lone pairs. This arrangement forms the molecular shape called <u>tetrahedral</u> . The bond angle is expected to be $109.5^\circ$ .

**Check Your Solution**

This arrangement fits the VSEPR notation  $\text{AX}_4$  which represents the tetrahedral molecular shape.