Draw The Lewis Structure Of Pcl And Then Choose The Appropriate Number Of Valence Electrons On The Central

Draw The Lewis Structure Of Pcl And Then Choose The Appropriate Number Of Valence Electrons On The Central

Understanding how to draw Lewis structures is fundamental in chemistry, as it provides insight into the bonding, geometry, and properties of molecules. In this article, we will walk through the process of drawing the Lewis structure for phosphorus pentachloride (PCl_5), determine the appropriate number of valence electrons on the central atom, and explore related concepts to deepen your understanding of molecular structure.

Introduction to Lewis Structures and Their Importance

Lewis structures, also known as Lewis dot structures, depict the bonding between atoms within a molecule and the lone pairs of electrons that may exist. They serve as a visual tool to:

- Predict molecular geometry
- Understand bonding and electron distribution
- Determine formal charges and stability
- Assist in understanding reactivity and polarity

For molecules like PCl_5, drawing an accurate Lewis structure is essential because it reveals the molecule's geometry, which influences its physical and chemical properties.

Step-by-Step Guide to Drawing the Lewis Structure of PCl_5

1. Determine the Total Number of Valence Electrons

The first step is to identify the total number of valence electrons available for bonding:

- Phosphorus (P) is in Group 15 (or 15th column) of the periodic table, contributing 5 valence electrons.
- Chlorine (Cl) is in Group 17, contributing 7 valence electrons each.

Calculating the total:

Total valence electrons = 1 × 5 (for P) + 5 × 7 (for Cl) = 5 + 35 = 40 electrons

2. Identify the Central Atom

In molecules with a single atom involved, the atom with the lowest electronegativity typically serves as the central atom. Phosphorus is less electronegative than chlorine, making it the central atom.

3. Arrange the Atoms and Connect Them with Single Bonds

- Place P in the center.
- Connect each Cl atom to P with a single bond.

This initial structure uses:

- 1 bond per Cl atom = 5 bonds total
- Each bond consists of 2 electrons, so total electrons used in bonding = 5 × 2 = 10 electrons

4. Complete the Octets (or Electron Counts) Around the Outer Atoms

- Each Cl atom needs 3 lone pairs (6 electrons) to complete its octet.
- Assign these lone pairs to each Cl atom.

Electrons assigned so far:

- 5 Cl atoms × 6 electrons (lone pairs) = 30 electrons
- Electrons used in bonds: 10 electrons

Total electrons assigned: 30 + 10 = 40 electrons, matching the total valence electrons.

5. Verify and Adjust for the Central Atom

- Phosphorus currently has 5 single bonds, each with 2 electrons, totaling 10 electrons around P.
- Phosphorus can expand its octet because it is in period 3 and can accommodate more than 8 electrons.

Since the electrons are fully assigned, and the total is correct, the Lewis structure for PCl_5 involves phosphorus bonded to five chlorine atoms, with each chlorine having three lone pairs, and phosphorus having five bonding pairs.

Lewis Structure of PCl_5

The Lewis structure can be represented as:

- P at the center.
- Five Cl atoms surrounding P, each connected via a single bond.
- Each Cl atom has three lone pairs.
- The phosphorus atom has no lone pairs but is bonded to five chlorine atoms.

Visually, it resembles a trigonal bipyramidal shape, which we will explore further in the geometry section.

Choosing the Appropriate Number of Valence Electrons on the Central Atom

Valence Electron Count for Phosphorus in PCl_5

In the case of PCl_5, phosphorus has expanded its octet to accommodate five bonding pairs. This is possible because:

- Phosphorus is in period 3 of the periodic table.
- Period 3 elements can utilize d-orbitals to expand their octet, although the role of d-orbitals in bonding is still debated. Conceptually, for Lewis structures, we assume this expansion is possible.

The number of electrons around phosphorus:

- 5 bonds × 2 electrons per bond = 10 electrons

Therefore, the valence electrons on the central atom are 10, which exceeds the octet rule but is consistent with known expanded octet behavior.

Understanding Electron Counting in the Context of PCl_5

The central phosphorus atom:

- Has 5 bonding pairs (from the 5 Cl atoms)
- No lone pairs
- Total electrons involved: 10

This expanded valence shell configuration is an exception to the octet rule, common in molecules with elements in period 3 or beyond.

Geometry and Shape of PCl_5

The electron pair arrangement around phosphorus in PCl_5 is based on five bonding pairs and no lone pairs, leading to specific molecular geometry.

1. Electron Geometry

- The five bonding pairs arrange themselves to minimize repulsion, resulting in a trigonal bipyramidal electron geometry.

2. Molecular Geometry

- Since there are no lone pairs on the central atom, the molecular shape mirrors the electron geometry: trigonal bipyramidal.

3. Bond Angles

- Equatorial positions: approximately 120° apart.
- Axial positions: approximately 90° to the equatorial bonds.

Understanding this geometry is critical because it influences the physical properties and reactivity of PCl_5.

Summary of Key Points

- The total valence electrons in PCl_5 are 40.
- Phosphorus is the central atom, with five chlorine atoms attached via single bonds.
- Phosphorus expands its octet to accommodate five bonding pairs, resulting in 10 electrons around it.
- The Lewis structure depicts phosphorus at the center with five single bonds to chlorine atoms, each with three lone pairs.
- The molecular geometry of PCl_5 is trigonal bipyramidal, consistent with VSEPR theory.
- Understanding electron counts and geometry helps predict the molecule's behavior and interactions.

Additional Tips for Drawing Lewis Structures

- Always verify the total number of valence electrons before starting.
- Choose the central atom based on electronegativity and the ability to expand octets.
- Use single bonds initially, then complete the octets/lone pairs.
- For molecules with expanded octets, remember that elements in period 3 and beyond can have more than 8 electrons.
- Confirm your structure by checking electron counts and formal charges to ensure stability.

Conclusion

Drawing Lewis structures like that of PCl_5 provides valuable insights into the bonding and molecular geometry of compounds. Recognizing the ability of certain elements to expand their valence shells is crucial in accurately depicting molecules with more than eight electrons around the central atom. By following systematic steps—calculating valence electrons, arranging atoms, distributing electrons, and verifying structures—you can confidently analyze a wide range of molecules, including those with expanded octets like PCl_5. Mastery of these concepts enhances your understanding of chemical bonding and prepares you for more advanced topics in chemistry.

Frequently Asked Questions

What is the first step in drawing the Lewis structure of PCl?

The first step is to determine the total number of valence electrons, which involves adding the valence electrons of phosphorus and chlorine atoms.

How many valence electrons does phosphorus have in PCl?

Phosphorus has 5 valence electrons.

How many valence electrons does each chlorine atom contribute in PCl?

Each chlorine atom contributes 7 valence electrons.

What is the total number of valence electrons for PCl?

The total number of valence electrons is 5 (from P) + 7 (from Cl) = 12 electrons.

How do you determine the central atom in PCl when drawing the Lewis structure?

Phosphorus is the central atom because it is less electronegative than chlorine and can form more bonds.

How many valence electrons should be assigned to the central phosphorus atom in PCl?

The central phosphorus atom should have 8 electrons around it in the Lewis structure, accounting for the bonding and lone pairs.

What is the appropriate number of valence electrons on the central atom when drawing PCl?

Phosphorus in PCl has 8 electrons in its valence shell in the Lewis structure, representing an octet.

How many bonding pairs are present in the Lewis structure of PCl?

There are three bonding pairs forming single bonds between phosphorus and each chlorine atom.

What is the overall shape of PCl based on its Lewis structure?

The molecular shape of PCl is tetrahedral if considering lone pairs, but with three bonds and a lone pair on phosphorus, it adopts a trigonal pyramidal shape.

Why is it important to choose the correct number of valence electrons when drawing Lewis structures?

Choosing the correct number of valence electrons ensures an accurate representation of bonding, electron distribution, and molecular geometry, which is crucial for understanding chemical properties.

Additional Resources

Draw The Lewis Structure Of PCl And Then Choose The Appropriate Number Of Valence Electrons On The Central Atom

Understanding Lewis structures is fundamental in chemistry, as they provide a visual representation of the bonding between atoms within a molecule and help predict properties like reactivity, polarity, and molecular geometry. In this detailed review, we'll focus on drawing the Lewis structure of phosphorus trichloride (PCl_3) and determining the appropriate number of valence electrons on the central atom, phosphorus (P). This exploration will delve into the steps for constructing Lewis structures, electron counting, considerations of formal charge, and the implications of the structure on molecular properties.

Introduction to Lewis Structures and Their Significance

Lewis structures, also known as Lewis electron dot structures, are diagrams that depict the bonding between atoms of a molecule and the lone pairs of electrons that may exist. They serve as a foundational tool for understanding molecular shape, polarity, reactivity, and other chemical properties.

Key purposes of Lewis structures include:

- Visualizing how atoms are bonded within a molecule.
- Determining the distribution of valence electrons.
- Predicting molecular geometry based on electron pair arrangements.
- Assessing the stability of molecules via formal charges.

Valence Electrons and the Central Atom: Phosphorus in PCl_3

Before constructing the Lewis structure, it's essential to identify the valence electrons for each atom involved.

Valence electrons of relevant elements:

- Phosphorus (P): 5 valence electrons (Group 15 / VA)
- Chlorine (Cl): 7 valence electrons (Group 17 / VIIA)

Total valence electrons in PCl_3:

- P contributes 5 electrons.
- Each Cl contributes 7 electrons, and there are three Cl atoms: $7 \times 3 = 21$ electrons.

Total valence electrons:

5 (P) + 21 (Cl) = 26 electrons

This total will guide the construction of the Lewis structure.

Step-by-Step Construction of the Lewis Structure of PCl_3

Constructing an accurate Lewis structure involves systematic steps:

1. Identify the central atom

- Typically, the atom that can form the most bonds or is less electronegative is chosen as the central atom.
- Phosphorus is less electronegative than chlorine (P: 2.19, Cl: 3.16), making phosphorus the central atom.

2. Arrange the atoms

- Place P in the center.
- Surround it with three Cl atoms.

3. Connect atoms with single bonds

- Draw single bonds from P to each Cl atom.
- Each single bond accounts for 2 electrons: 3 bonds × 2 electrons = 6 electrons used.

4. Distribute remaining electrons

- Subtract the bonding electrons from total valence electrons:

Remaining electrons = 26 total - 6 used in bonds = 20 electrons

- Distribute remaining electrons as lone pairs on the terminal atoms (Cl atoms) first, since they are less central.

5. Complete octets on terminal atoms

- Each Cl needs 8 electrons (octet):
- Each Cl already has 2 electrons in the single bond.
- To complete octet, each Cl needs 6 more electrons (3 lone pairs).
- Allocate 6 electrons (3 lone pairs) to each Cl atom:

3 Cl atoms × 6 electrons = 18 electrons

Remaining electrons = 20 - 18 = 2 electrons

6. Assign remaining electrons to the central atom

- The central atom (P) now has 6 electrons from the three bonds (each bond has 2 electrons).
- Phosphorus currently has 6 electrons around it and needs 8 to complete its octet.
- Since only 2 electrons remain, P can accept a lone pair or form double bonds with Cl atoms to fulfill octet requirements.

7. Determine the best Lewis structure

- Phosphorus has 5 valence electrons and forms three single bonds (6 electrons), which suggests it's slightly deficient in electrons for an octet.
- To satisfy the octet rule, consider the possibility of double bonds.

Incorporating Double Bonds for Complete Octet

While the initial structure with three single bonds is valid, phosphorus can expand its octet because it's in period 3, which allows for more than 8 electrons.

Options:

- Form double bonds with one or more Cl atoms to give phosphorus an octet.
- However, in PCl_3, the most common and stable structure is with phosphorus forming three single bonds, with formal charges minimized.

Note on Formal Charges:

- Formal charge is a hypothetical charge assigned to atoms in a Lewis structure, indicating electron distribution.
- Structures with minimal formal charges are generally more stable.

Calculating Formal Charges to Validate the Lewis Structure

Formal charge formula:

$$
\text{Formal charge} = \text{Valence electrons} - (\text{Lone pair electrons} + \frac{1}{2} \text{Bonding electrons})
$$

Applying to PCl_3 with three single bonds:

- Phosphorus (P):

- Valence electrons: 5
- Lone pairs: 0 (no lone pairs on P)
- Bonding electrons: 3 bonds × 2 electrons = 6

$$
\text{Formal charge} = 5 - (0 + \frac{6}{2}) = 5 - 3 = +2
$$

- Chlorine atoms:

- Valence electrons: 7
- Lone pairs: 3 (6 electrons)
- Bonding electrons: 2 (single bond)

$$
\text{Formal charge} = 7 - (6 + \frac{2}{2}) = 7 - (6 + 1) = 0
$$

Implication:

- The central P atom carries a formal charge of +2, which indicates that the structure is less stable.
- To improve stability, consider structures where P has a formal charge closer to zero.

Alternative Lewis Structures: Double Bonds and Resonance

Possibility of double bonds:

- Phosphorus's ability to expand its octet allows for double bonds with Cl to reduce formal charges.
- For instance, forming one or two double bonds with Cl atoms can distribute electrons more evenly.

Limitations:

- Such structures are less common because PCl_3 predominantly exists with three single bonds.
- Instead, structures with formal charges of +1 on P and negative charges on Cl can be more stable, but are generally less favored.

Resonance structures:

- In PCl_3, resonance is minimal because the bonds are primarily single bonds.
- However, in related molecules, resonance can delocalize electrons to stabilize the structure.

Final Lewis Structure of PCl_3

Based on the above analysis:

- Structure:

- Phosphorus in the center.
- Three single bonds to three chlorine atoms.
- Each Cl atom has three lone pairs.
- No double bonds are necessary or typical for PCl_3.

- Electron count:

- P has 3 bonding pairs and no lone pairs, with a formal charge of +1 if accounting for formal charges.
- Cl atoms are neutral with full octets.

- Molecular geometry:

- The arrangement of electron pairs around P is tetrahedral, with one position occupied by a lone pair if considering electron pairs, or trigonal pyramidal if focusing on the bonding atoms only.

Choosing the Appropriate Number of Valence Electrons on the Central Atom

Summary:

- Phosphorus has 5 valence electrons.
- When forming PCl_3, it forms three single bonds, effectively sharing electrons with three Cl atoms.
- The total electrons associated with P in this structure can be counted as:

- 3 bonding pairs (6 electrons),
- With the remaining electrons (if any), P can expand its octet due to its third period position.

In the Lewis structure:

- Number of valence electrons on P: 5 (its valence electrons).
- Electrons involved in bonding: 6 (from three bonds).
- Electrons around P in the structure: 6 electrons, which is less than the octet, but acceptable because P can expand its octet.

Implications:

- The appropriate number of valence electrons on the central atom (P) in the Lewis structure of PCl_3 is 5 valence electrons.
- The electrons involved in bonding are shared with Cl atoms, which are more electronegative, leading to polar bonds.

Impacts of Lewis Structure on Molecular Properties

Understanding the Lewis structure and valence electron distribution influences predictions about:

- Molecular Geometry:

- PCl_3 adopts a trigonal pyramidal shape based on VSEPR theory.
- Electron pairs (including lone pairs) repel each other, influencing the shape.

- Polarity:

- The molecule is polar because of the difference in electronegativity between P and Cl and the asymmetrical shape.
- The dipole moment results from the polar P-Cl

Draw The Lewis Structure Of Pcl And Then Choose The Appropriate Number Of Valence Electrons On The Central

Draw The Lewis Structure Of Pcl And Then Choose The Appropriate Number Of Valence Electrons On The Central

Related Articles

- Line Corporation's Balance Sheet Showed The Following Amounts For Their Liability And Stockholders' Equity
- In Each Of Problems 4 Through 9, Find The General Solution Of The Given Differential Equation. In Problems
- If The Content Of T4: 0.ACC Is Copied Into N7: 0 Through N7:4 Memory Locations, This Process Is Considered

Back to Home