Pearson

5.3: Writing Lewis Structures for Molecular Compounds and Polyatomic Ions

Key Concept Video **Writing Lewis Structures for Molecular Compounds**

In Chapter 4 we saw how the Lewis model can be used to describe ionic and covalent bonds, and in Section 5.2 we saw how some covalent bonds are polar. We now turn to the basic sequence of steps involved in writing Lewis structures for given combinations of atoms.

> Often, chemical formulas are written in a way that provides clues to how the atoms are bonded together. For example, CH_3OH indicates that three hydrogen atoms and the oxygen atom are bonded to the carbon atom but the fourth hydrogen atom is bonded to the oxygen atom.

Writing Lewis Structures for Molecular Compounds

To write a Lewis structure for a molecular compound, follow these steps:

1. **Write the correct skeletal structure for the molecule.** The Lewis structure of a molecule must have the atoms in the correct positions. For example, you could not write a Lewis structure for water if you started with the hydrogen atoms next to each other and the oxygen atom at the end (HHO). In nature, oxygen is the central atom and the hydrogen atoms are *terminal* (at the ends). The correct skeletal structure is HOH. The only way to determine the skeletal structure of a molecule with absolute certainty is to examine its structure experimentally.

   However, you can write likely skeletal structures by remembering two guidelines. First, *hydrogen atoms are always terminal*. Hydrogen does not ordinarily occur as a central atom because central atoms must form at least two bonds, and hydrogen, which has only a single valence electron to share and requires only a duet, can form just one. Second, *put the more electronegative elements in terminal positions* and the less electronegative elements (other than hydrogen) in the central position. Later in this chapter, you will learn how to distinguish between competing skeletal structures by applying the concept of formal charge.

   > There are a few exceptions to this rule, such as diborane (B_2H_6), which contains *bridging hydrogens*, but these are rare and cannot be adequately addressed by the Lewis model.

2. **Calculate the total number of electrons for the Lewis structure by summing the valence electrons of each atom in the molecule.** Remember that the number of valence electrons for any main-group element is equal to its group number in the periodic table. *If you are writing a Lewis structure for a polyatomic ion, you must consider the charge of the ion when calculating the total number of electrons.* Add one electron for each negative charge and subtract one electron for each positive charge. Don't worry about which electron comes from which atom—only the total number is important.
3. **Distribute the electrons among the atoms, giving octets (or duets in the case of hydrogen) to as many atoms as possible.** Begin by placing two electrons between every two atoms. These represent the minimum number of bonding electrons. Then distribute the remaining electrons as lone pairs, first to terminal atoms and then to the central atom, giving octets (or duets for hydrogen) to as many atoms as possible.

   > Sometimes distributing all the remaining electrons to the central atom results in more than an octet. This is called an expanded octet and is covered in Section 5.5.

4. **If any atoms lack an octet, form double or triple bonds as necessary to give them octets.** Do this by moving lone electron pairs from terminal atoms into the bonding region with the central atom.

5. Check. Count the number of electrons in the Lewis structure. The total should equal the number from Step 2.

Example 5.2 Writing Lewis Structures

PROCEDURE FOR

Writing Lewis Structures for Covalent Compounds

Write the Lewis structure for CO_2

1. Write the correct skeletal structure for the molecule.

SOLUTION

Because carbon is the less electronegative atom, put it in the central position.

O C O

2. Calculate the total number of electrons for the Lewis structure by summing the valence electrons of each atom in the molecule.

Total number of electrons for Lewis structure =

$$\begin{pmatrix}\text{number of}\\ \text{valence}\\ e^- \text{ for C}\end{pmatrix} + 2\begin{pmatrix}\text{number of}\\ \text{valence}\\ e^- \text{ for O}\end{pmatrix}$$
$$= 4 + 2(6) = 16$$

3. Distribute the electrons among the atoms, giving octets (or duets for hydrogen) to as many atoms as possible. Begin with the bonding electrons and then proceed to lone pairs on terminal atoms and finally to lone pairs on the central atom.

Bonding electrons are first.

O:C:O

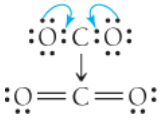
(4 of 16 electrons used)

Lone pairs on terminal atoms are next.

(16 of 16 electrons used)

4. If any atom lacks an octet, form double or triple bonds as necessary to give them octets.

Since carbon lacks an octet, move lone pairs from the oxygen atoms to bonding regions to form double bonds.



5. Check. Count the number of electrons in the Lewis structure. The total should equal the number from Step 2.

Step 2.

The Lewis structure has 16 electrons as calculated in Step 2.

FOR PRACTICE 5.2

Write the Lewis structure for CO.

Example 5.3 Writing Lewis Structures

PROCEDURE FOR

Writing Lewis Structures for Covalent Compounds

Write the Lewis structure for NH_3.

1. Write the correct skeletal structure for the molecule.

SOLUTION

Since hydrogen is always terminal, put nitrogen in the central position.

H N H
H

2. Calculate the total number of electrons for the Lewis structure by summing the valence electrons of each atom in the molecule.

Total number of electrons for Lewis structure =

$$\begin{pmatrix}\text{number of}\\ \text{valence}\\ e^- \text{ for N}\end{pmatrix} + 3\begin{pmatrix}\text{number of}\\ \text{valence}\\ e^- \text{ for H}\end{pmatrix}$$
$$= 5 + 3(1) = 8$$

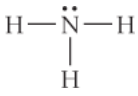
Distribute the electrons among the atoms, giving octets (or duets for hydrogen) to as many atoms as possible. Begin with the bonding electrons and then proceed to lone pairs on terminal atoms and finally to lone pairs on the central atom.

Bonding electrons are first.

(6 of 8 electrons used)

Lone pairs on terminal atoms are next, but none are needed on hydrogen.

Lone pairs on central atom are last.



(8 of 8 electrons used)

4. If any atom lacks an octet, form double or triple bonds as necessary to give them octets.

Since all of the atoms have octets (or duets for hydrogen), the Lewis structure for NH_3 is complete, as shown in the previous step.

5. Check. Count the number of electrons in the Lewis structure. The total should equal the number from Step 2.

The Lewis structure has 8 electrons as calculated in Step 2.

FOR PRACTICE 5.3

Write the Lewis structure for H_2CO.

Interactive Worked Example 5.2 Writing Lewis Structures

Writing Lewis Structures for Polyatomic Ions

Write Lewis structures for polyatomic ions by following the same procedure, but pay special attention to the charge of the ion when calculating the number of electrons for the Lewis structure. Add one electron for each negative charge and subtract one electron for each positive charge. Write the Lewis structure for a polyatomic ion within brackets with the charge of the ion in the upper right-hand corner, outside the bracket.

Example 5.4 Writing Lewis Structures for Polyatomic Ions

Write the Lewis structure for the NH_4^+ ion.

SOLUTION

Begin by writing the skeletal structure. Since hydrogen is always terminal, put the nitrogen atom in the central position.

Calculate the total number of electrons for the Lewis structure by summing the number of valence electrons for each atom and subtracting 1 electron for the 1+ charge.

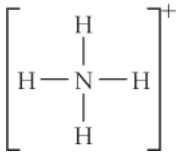
Total number of electrons for Lewis structure
= (number of valence e^- in N) + (number of valence e^- in H) − 1
= 5 + 4(1) + 1
= 8

Subtract 1 e^- to account for 1+ charge of ion.

Place two bonding electrons between every two atoms. Since all of the atoms have complete octets, no double bonds are necessary.

(8 of 8 electrons used)

Write the Lewis structure in brackets with the charge of the ion in the upper right-hand corner.



FOR PRACTICE 5.4 Write the Lewis structure for the hypochlorite ion, ClO^-.

Interactive Worked Example 5.4 **Writing Lewis Structures for Polyatomic Ions**