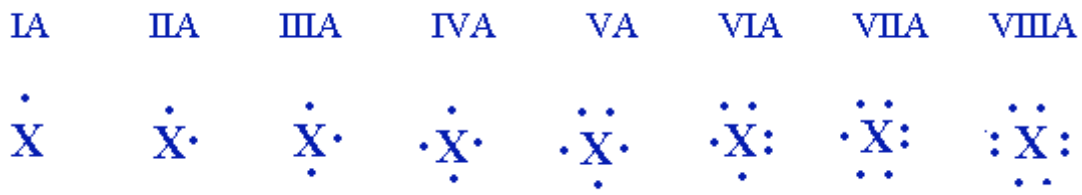
Lewis Structures

Molecular formula, such as H_2O, gives us only the number and kind of atoms bonded in a molecule, but does not provide any greater details as to how the atoms are bonded to one another in a given molecule. Lewis structures, on the other hand, provide a greater detail in terms of (a) how the atoms are distributed around each other, and (b) how the bonds - single, double or triple- are arranged in molecules. In other words, Lewis structures provide the method of distributing the valence electrons subject to certain requirements. Even though, they do not provide the complete picture of covalent bonding, they are the great tool to understand the bonding scheme in many compounds, especially, those obeying octet rules.

Before you start writing Lewis structures, you must know the number of valence electrons in atoms, particularly those of A group elements (Representative elements) and noble gases. It is easy to remember these because the number of valence electrons corresponds to the group number as indicated in the following table I.

Table I. Lewis dot symbols (notations) for A group elements and noble gases.



One dot represents one electron. Group IA has 1 valence electron, group IIA has 2 valence electrons, group IIIA has 3 valence electrons, group IVA has 4 valence electrons, group VA has 5 valence electrons, group VIA has 6 valence electrons, group VIIA has 7 valence electrons, and group VIIIA (noble gases) has 8 valence electrons

Writing Lewis Structures

There are few different approaches to write the Lewis structures, but here one of them is presented. Follow the following steps.

Step 1. Count the total number of valence electrons for all the atoms based on the Lewis dot symbols. For polyatomic atomic anions add number electrons equal to number of negative charges. For polyatomic cations, subtract the number of electrons equal to the total positive number of positive charges.

Step 2. Count the total number of electrons needed to obey the octet rule (8 electrons in the valence shell) except H that obeys duet rule (2 electrons in the valence shell).

Step 3. Subtract total number of valence electrons (step 1) from the total number of electrons needed to obey the respective rules (step 2) to come with number of electrons engaged in bonding (bonding electrons).

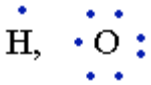
*Step 4***.** Divide the bonding electrons (step 3) with 2 to determine number of single bond.

Step 5. With information given in either step 3 or 4 or both, write the Lewis structure; first write the skeletal structure using atomic symbols and making an educated guess which atom goes in the center and which atoms go on terminal (end). Most of the times, you can guess this by looking at the given molecular formula.

Examples (molecule)

Write the Lewis structure for water (H_2O), in which hydrogen atoms are bonded to the oxygen atom.

Answer:

Lewis dot symbols**:** 

Step 1. Referring to above dot symbols, count the total number of valence electrons.

Total number of valence electrons = 1 (for H) + 1 (for H) + 6 (for O) = 8 electrons

Step 2: H obeys the duet rule and O obeys the octet rule.

Number of electrons needed to obey the rules = 2 (for H) + 2 (for H) + 8 (O atoms)
= 12 electrons.

Step 3. Number of electrons engaged in bonding = 12 electrons - 8 electrons = 4 electrons.

Step 4. Number of single bonds = 4 electrons / 2 electrons = 2 single bonds.

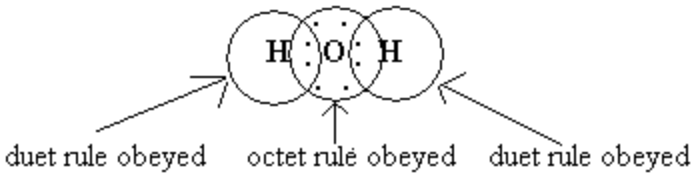
Step 5. Now place the O atom in the center and one H atom on one side and another H atom on the other side.

H O H

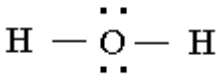
You have 4 electrons (or 2 bonds) to be distributed. So, place 2 electrons between H and O, and 2 electrons between O and H.

H : O : H

Both H atoms obey the duet rule and you have still 4 electrons to be distributed. So, place 4 electrons



It is preferable to put a bond between the atoms. By doing that the structure becomes less cluttered and also looks nicer.

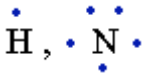


The 4 electrons (4 dots) are known as non-bonding electrons and 2 electrons between H and O (indicated as a single bond) and 2 electrons between O and H (indicated as a single bond) are known as bonding electrons.

Example (cation)

Write the Lewis structure for ammonium ion (NH_4^+)

Answer

Lewis dot symbols**:** 

Step 1. Referring to above dot symbols, count the total number of valence electrons.

Total number of valence electrons = 1 (for H) + 1 (for H)+ 1 (for H) + 1 (for H)
+ 5 (for N) – 1 (one positive charge)
= 8 electrons

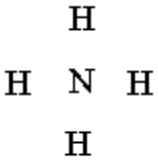
Step 2: H obeys the duet rule and N obeys the octet rule.

Number of electrons needed to obey the rules = 2 (for H) + 2 (for H) + 2(for H)
+ 2 (for H) + 8 (N atoms)
= 16 electrons.

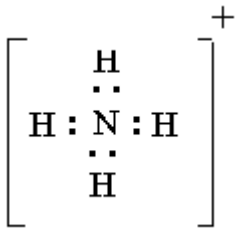
Step 3. Number of electrons engaged in bonding = 16 electrons - 8 electrons = 8 electrons.

Step 4. Number of single bonds = 8 electrons / 2 electrons = 4 single bonds.

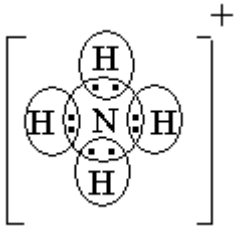
Step 5. Now place the N atom in the center and H atoms on 4 sides.



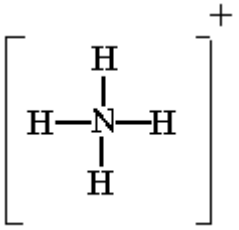
You have 8 electrons (or 4 bonds) to be distributed. So, place 2 electrons between each H and N. Enclose in a square bracket and put + sign on the upper right corner to indicate that it is a positive ion with 1 plus charge.



Now you can see each H atom obeys the duet rule and N atom obeys octet rule.



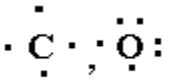
Now replace bonding electrons with single bonds.



Example (anion)

Write the Lewis structure for carbonate ion (CO_3^{2-}).

Answer

Lewis dot symbols**:** 

Step 1. Referring to above dot symbols, count the total number of valence electrons.

Total number of valence electrons = 4 (for C) + 6 (for O) + 6 (for O) + 6 (for O)
+ 2 (for 2 negative charges)
= 24 electrons

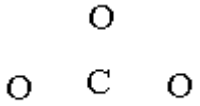
Step 2: Both atoms obey octet rule.

Number of electrons needed to obey the rules = 8(for C) + 8 (for O) + 8(for O)
+ 8 (for O)
= 32 electrons.

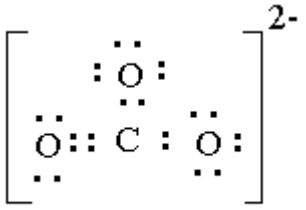
Step 3. Number of electrons engaged in bonding = 32 electrons - 24 electrons = 8 electrons.

Step 4. Number of single bonds = 8 electrons / 2 electrons = 4 single bonds.

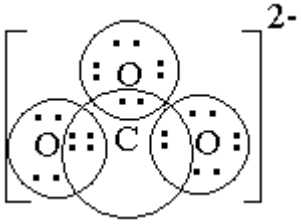
Step 5. Now place the C atom in the center and O atoms on any 3 sides.



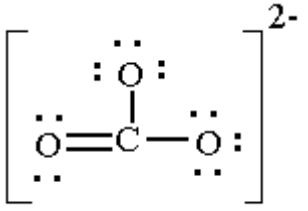
You have 8 electrons (or 4 bonds) to be distributed. First place the single bond (2 dots) between each O and C. You have placed 6 electrons so far. You have 2 more left, place them between any one of the O and C. Now you have distributed all bonding electrons. Total you have 24 valence electrons and still you have 16 (= 24-8) valence electrons to be distributed. Place required number of electrons around each O atom to complete the octet.



Now you can see that all the atoms obey the octet rule.



Now replace bonding electrons with single bond.



Note that the double can go in any one of the three equivalent positions (between O and C). So there are 3 equivalent Lewis structures - all are correct.