Solutions to Practice Problems in Chapter 4 Chemical Bonding and Properties of Matter

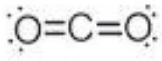
Drawing Lewis Structures of Molecules
(Student textbook page 232)

1. Draw the Lewis structure for a molecule of carbon dioxide, $CO_2(g)$.

What Is Required?
You need to draw the Lewis structure for carbon dioxide, CO_2 (g).

What Is Given?
The chemical formula tells you that the molecule consists of one carbon atom and two oxygen atoms.

Plan Your Strategy	Act on Your Strategy
Identify the least electronegative atom and make it the central atom in the structure.	The least electronegative atom is carbon. Therefore, it is the central atom.
Draw a skeleton structure of the carbon atom with one single bond between it and each of the two oxygen atoms.	O-C-O
Determine the total number of valence electrons in all the atoms of the molecule. The carbon atom has four valence electrons, and the oxygen atoms each have six valence electrons.	$V = \left(1 \cancel{\text{ C atom}} \times \frac{4e^-}{\cancel{\text{C atom}}}\right) + \left(2 \cancel{\text{ O atoms}} \times \frac{6e^-}{\cancel{\text{O atom}}}\right)$ $= 4e^- + 12e^-$ $= 16e^-$
Determine the total number of electrons needed for each atom to achieve noble gas configuration.	$T = \left(1 \cancel{\text{ C atom}} \times \frac{8e^-}{\cancel{\text{C atom}}}\right) + \left(2 \cancel{\text{ O atoms}} \times \frac{8e^-}{\cancel{\text{O atoms}}}\right)$ $= 8e^- + 16e^-$ $= 24e^-$

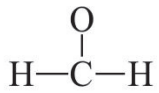
Determine the number of shared electrons and the resulting number of bonds.	$S = T - V$ $= 24e^- - 16e^-$ $= 8e^-$ $\text{bonds} = \frac{S}{2} = \frac{8}{2} = 4$ covalent bonds
Draw the structure with any necessary double or triple bonds. To create four covalent bonds, put a double bond between the C atom and each of the O atoms.	O = C = O
Determine the number of non-bonding electrons and add them as lone pairs to satisfy the octet rule for all atoms.	$NB = V - S$ $= 16e^- - 8e^-$ $= 8e^-$
Complete the Lewis structure. Because there are 8 non-bonding electrons, there are 4 lone pairs to place. Put 2 lone pairs on each O atom.	

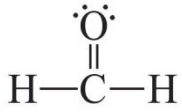
Check Your Solution
Each atom has eight valence electrons which achieves a noble gas configuration. All of the electrons have been accounted for.

2. Draw the Lewis structure for a molecule of formaldehyde (methanal), $CH_2O(g)$.

What Is Required?
You need to draw the Lewis structure for formaldehyde (methanal), $CH_2O(g)$.

What Is Given?
The chemical formula tells you that there is one carbon atom, two hydrogen atoms, and one oxygen atom.

Plan Your Strategy	Act on Your Strategy
Identify the least electronegative atom and make it the central atom in the structure.	The least electronegative atom is carbon therefore it is the central atom.
Draw a skeleton structure of the carbon atom with one single bond between it and each of the other atoms.	
Determine the total number of valence electrons in all the atoms of the molecule. The carbon atom has four valence electrons, the hydrogen atoms each have one valence electron, and the oxygen atom has six valence electrons.	$V = \left(1 \cancel{\text{C atom}} \times \frac{4e^-}{\cancel{\text{C atom}}}\right) + \left(1 \cancel{\text{O atoms}} \times \frac{6e^-}{\cancel{\text{O atom}}}\right) + \left(2 \cancel{\text{H atoms}} \times \frac{1e^-}{\cancel{\text{H atom}}}\right)$ $= 4e^- + 6e^- + 2e^-$ $= 12e^-$

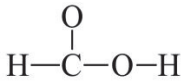
Determine the total number of electrons needed for each atom to achieve noble gas configuration.	$T = \left(1\ \cancel{\text{C atom}} \times \frac{8e^-}{\cancel{\text{C atom}}}\right) + \left(1\ \cancel{\text{O atoms}} \times \frac{8e^-}{\cancel{\text{O atom}}}\right) + \left(2\ \cancel{\text{H atoms}} \times \frac{2e^-}{\cancel{\text{H atom}}}\right)$ $= 8e^- + 8e^- + 4e^-$ $= 20e^-$
Determine the number of shared electrons and the resulting number of bonds.	$S = T - V$ $= 20e^- - 12e^-$ $= 8e^-$ $\text{bonds} = \frac{S}{2} = \frac{8}{2} = 4$ covalent bonds
Draw the structure with any necessary double or triple bonds. Hydrogen cannot form double bonds because the total number of electrons in its valence shell must be two. Therefore, put a double bond between the C atom and the O atom.	
Determine the number of non-bonding electrons and add them as lone pairs to satisfy the octet rule for all atoms.	$NB = V - S$ $= 12e^- - 8e^-$ $= 4e^-$
Complete the Lewis structure. Because there are 4 non-bonding electrons, there are 2 lone pairs to place. Put both lone pairs on the O atom.	

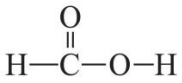
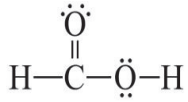
Check Your Solution
Each atom has a filled outer shell of electrons which achieves a noble gas configuration. The hydrogen atoms have only two electrons but that is the noble gas configuration of helium. All of the electrons have been accounted for.

3. Formic acid, or methanoic acid, HCOOH(ℓ), is found naturally in ant venom. Synthesized formic acid is used for its antibacterial and preservative properties in a variety of animal feeds, among other uses. Given that carbon is the central atom of the molecule, with hydrogen, oxygen, and hydroxyl groups, draw its Lewis structure.

What Is Required?
You need to draw the Lewis structure for a molecule of methanoic acid, HCOOH(ℓ).

What Is Given?
The chemical formula tells you that the molecule consists of one carbon atom, two hydrogen atoms, and two oxygen atoms.
You are also told that the carbon atom is the central atom and is bonded to a hydrogen atom, an oxygen atom, and a hydroxyl group.

Plan Your Strategy	Act on Your Strategy
Draw a skeleton structure of the carbon atom with one single bond between it and each of the other atoms or groups as described.	
Determine the total number of valence electrons in all the atoms of the molecule. The carbon atom has four valence electrons, the hydrogen atoms each have one valence electron, and the oxygen atoms have six valence electrons each.	$V = \left(1\ \cancel{\text{C atom}} \times \frac{4e^-}{\cancel{\text{C atom}}}\right) + \left(2\ \cancel{\text{O atoms}} \times \frac{6e^-}{\cancel{\text{O atom}}}\right) + \left(2\ \cancel{\text{H atoms}} \times \frac{1e^-}{\cancel{\text{H atom}}}\right)$ $= 4e^- + 12e^- + 2e^-$ $= 18e^-$
Determine the total number of electrons needed for each atom to achieve noble gas configuration.	$T = \left(1\ \cancel{\text{C atom}} \times \frac{8e^-}{\cancel{\text{C atom}}}\right) + \left(2\ \cancel{\text{O atoms}} \times \frac{8e^-}{\cancel{\text{O atoms}}}\right) + \left(2\ \cancel{\text{H atoms}} \times \frac{2e^-}{\cancel{\text{H atoms}}}\right)$ $= 8e^- + 16e^- + 4e^-$ $= 28e^-$

Determine the number of shared electrons and the resulting number of bonds.	$S = T - V$ $= 28e^- - 18e^-$ $= 10e^-$ $\text{bonds} = \frac{S}{2} = \frac{10}{2} = 5$ covalent bonds
Draw the structure with any necessary double or triple bonds. H atoms cannot form double bonds. To create five covalent bonds, put a double bond between the C atom and the O atom that is not part of the hydroxyl group. Put a single bond between the C atom and one H atom, and between the O atom and the H atom of the hydroxyl.	
Determine the number of non-bonding electrons and add them as lone pairs to satisfy the octet rule for all atoms.	$NB = V - S$ $= 18e^- - 10e^-$ $= 8e^-$
Complete the Lewis structure. Because there are 8 non-bonding electrons, there are 4 lone pairs to place. Put two lone pairs on each O atom.	

Check Your Solution

Each atom has a filled outer shell of electrons which achieves a noble gas configuration. The hydrogen atoms have only two electrons, but that is the noble gas configuration of helium. All of the electrons have been accounted for.