Unit 1 The Diversity of Matter and Chemical Bonding
Chapter 1 Chemical Bonding

Solutions to Practice Problems

1.
Problem
Draw a Lewis structure to represent a molecule having one carbon atom bonded to two hydrogen atoms and two chlorine atoms. This compound is called dichloromethane. It is also called methylene chloride and is sometimes used as a paint stripper.

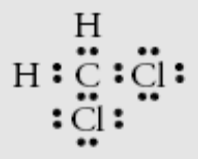
What is Required?
You must draw the Lewis configuration of the CH_2Cl_2 molecule.

What is Given?
The molecule has one carbon atom, two hydrogen atoms, and two chlorine atoms.

Plan Your Strategy
To satisfy the octet rule, the carbon atom and the chlorine atom must have eight electrons in their outer energy level and each hydrogen atom must have two electrons to fill its outer energy level.

Act on Your Strategy
Step 1. Determine the number of valence electrons in the outer energy level of each element.
Step 2. Draw the Lewis structure of each atom and fit them together, joined side by side, by one pair of electrons. Remember that in a Lewis structure with more than four electrons, the pairs of electrons must fill consecutively around the atom, and not arbitrarily.

CH_2Cl_2



Check Your Solution
Count the number of electrons (bonding and non-bonding) around each atom. The carbon and chlorine atoms have eight electrons in their outer energy level and each hydrogen atom has two electrons to fill its outer energy level.

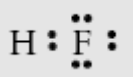
2.
Problem
Draw a Lewis structure to represent a molecule having one hydrogen atom bonded to one fluorine atom. This compound, hydrogen fluoride, is sometimes used to etch glass.

What is Required?
You must draw the Lewis configuration of the HF molecule.

What is Given?
The molecule has one fluorine atom and one hydrogen atom.

Plan Your Strategy
To satisfy the octet rule, the fluorine atom must have eight electrons in its outer energy level and the hydrogen atom must have two electrons in its outer energy level.
Act on Your Strategy
Step 1. Determine the number of valence electrons in the outer energy level of each element.
Step 2. Draw the Lewis structure of each atom and fit them together, joined side by side, by one pair of electrons. Remember that in a Lewis structure with more than four electrons, the pairs of electrons must fill consecutively around the atom, and not arbitrarily.

HF



Check Your Solution
Count the number of electrons (bonding and non-bonding) around each atom. The fluorine atom has eight electrons in its outer energy level and the hydrogen atom has two electrons in its outer energy level.

3.
Problem
Draw a Lewis structure to represent a molecule having three hydrogen atoms bonded to one nitrogen atom in this compound that is found in some cleaning solutions.

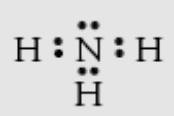
What is Required?
You must draw the Lewis configuration of the NH_3 molecule.

What is Given?
The molecule has one nitrogen atom and three hydrogen atoms.

Plan Your Strategy
To satisfy the octet rule, the nitrogen atom must have eight electrons in its outer energy level and each hydrogen atom must have two electrons in its outer energy level.

Act on Your Strategy
Step 1. Determine the number of valence electrons in the outermost shell of each element.
Step 2. Draw the Lewis structure of each atom and fit them together, joined side by side, by one pair of electrons. Remember that in a Lewis structure with more than four electrons, the pairs of electrons must fill consecutively around the atom, and not arbitrarily.

NH_3



Check Your Solution
Count the number of electrons (bonding and non-bonding) around each atom. The nitrogen atom has eight electrons in its outer energy level and each hydrogen atom has two electrons in its outer energy level.

4.
Problem
Draw a Lewis structure to represent one carbon atom bonded to two sulfur atoms. This compound, carbon disulfide, is sometimes found in gases from volcanic eruptions and in marsh gas.

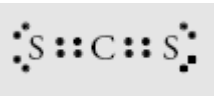
What is Required?
You must draw the Lewis configuration of the CS_2 molecule.

What is Given?
The molecule has one carbon atom and two sulfur atoms.

Plan Your Strategy
To satisfy the octet rule, the carbon atom and each sulfur atom must have eight electrons in its outer energy level.

Act on Your Strategy
Step 1. Determine the number of valence electrons in the outer energy level of each element.
Step 2. Draw the Lewis structure of each atom and fit them together, joined side by side, by one pair of electrons. Remember that in a Lewis structure with more than four electrons, the pairs of electrons must fill consecutively around the atom, and not arbitrarily.
Step 3. For those elements still left with unpaired electrons, join them together again into double or triple bonds.

CS_2



Check Your Solution
Count the number of electrons (bonding and non-bonding) around each atom. Each carbon atom and each sulfur atom has eight electrons in its outer energy level.

5.
Problem
Draw a Lewis structure to represent a central carbon atom bonded to a hydrogen atom and to a nitrogen atom. This is a toxic compound called hydrogen cyanide.

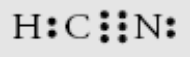
What is Required?
You must draw the Lewis configuration of the HCN molecule.

What is Given?
The molecule has one carbon atom, one nitrogen atom, and one hydrogen atom.

Plan Your Strategy
To satisfy the octet rule, the carbon atom and the nitrogen atom must have eight electrons in their outer energy levels and the hydrogen atom must have two electrons in its outer energy level.

Act on Your Strategy
Step 1. Determine the number of valence electrons in the outermost energy level of each element.
Step 2. Draw the Lewis structure of each atom and fit them together, joined side by side, by one pair of electrons. Remember that in a Lewis structure with more than four electrons, the pairs of electrons must fill consecutively around the atom, and not arbitrarily.
Step 3. For those elements still left with unpaired electrons, join them together again into double or triple bonds.

HCN



Check Your Solution
Count the number of electrons (bonding and non-bonding) around each atom. The carbon and nitrogen atoms each have eight electrons in their outer energy levels and the hydrogen atom has two electrons in its outer energy level.

6.
Problem
Draw a Lewis structure to represent a molecule having two carbon atoms bonded to each other and two hydrogen atoms bonded to each of the two carbon atoms. This compound, called ethene, or more commonly, ethylene, is used in the plastics industry.

What is Required?
You must draw the Lewis configuration of the C_2H_4 molecule.

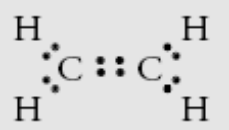
What is Given?
The molecule has two carbon atoms and four hydrogen atoms.

Plan Your Strategy
To satisfy the octet rule, each carbon atom must have eight electrons in its outer energy level and each of the four hydrogen atoms must have two electrons in its outer energy level.

Act on Your Strategy

Step 1. Determine the number of valence electrons in the outermost energy level of each element.
Step 2. Draw the Lewis structure of each atom and fit them together, joined side by side, by one pair of electrons. Remember that in a Lewis structure with more than four electrons, the pairs of electrons must fill consecutively around the atom, and not arbitrarily.
Step 3. For those elements still left with unpaired electrons, join them together again into double or triple bonds.

C_2H_4



Check Your Solution
Count the number of electrons (bonding and non-bonding) around each atom. Each carbon atom has eight electrons in its outer energy level and each of the four hydrogen atoms has two electrons in its outer energy level.

7.
Problem
Draw the Lewis structure for $NH_3(g)$.

What is Required?
You must draw the Lewis structure for $NH_3(g)$.

What is Given?
The chemical formula, $NH_3(g)$, tells you that there are three hydrogen atoms and one nitrogen atom in this molecule.

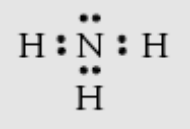
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(1\ \text{N atom} \times \frac{5\,e^-}{\text{N atom}}) + (3\ \text{H atoms} \times \frac{1\ e^-}{\text{H atom}}) = 8\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Nitrogen has three unpaired electrons and hydrogen has one unpaired electron. Therefore, nitrogen is the central atom. Draw a skeleton structure with one pair of bonding electrons between each hydrogen atom and the central nitrogen atom.
Step 3. Place a lone electron pair around the nitrogen atom to form an octet. The skeleton structure has eight electrons, which is the same as the total number of valence electrons in **Step 1**. The number of electrons is correct.

NH_3



Check Your Solution
The nitrogen atom has eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

8.
Problem
Draw the Lewis structure for $CH_4(g)$.

What is Required?
You must draw the Lewis structure for $CH_4(g)$.

What is Given?
The chemical formula, $CH_4(g)$, tells you that there are four hydrogen atoms and one carbon atom in this molecule.

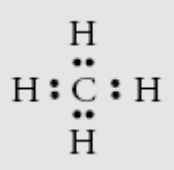
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(1\text{ C atom} \times \frac{4\text{ e}^-}{\text{C atom}} + (4\text{ H atoms} \times \frac{1\text{ e}^-}{\text{H atom}}) = 8\text{ e}^-$$

Step 2. Select the atom with the most unpaired electrons. Carbon has four unpaired electrons and each hydrogen has one unpaired electron. Therefore, carbon is the central atom. Draw a skeleton structure with one pair of bonding electrons between each hydrogen atom and the central carbon atom.
Step 3. The skeletal structure has eight electrons which is the same as the total number of valence electrons in step 1. The number of electrons is correct.

CH_4



Check Your Solution
The carbon atom has eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

9.

Problem

Draw the Lewis structure for $CF_4(g)$.

What is Required?

You must draw the Lewis structure for $CF_4(g)$.

What is Given?

The chemical formula, $CF_4(g)$, tells you that there are four fluorine atoms and one carbon atom in this molecule.

Plan Your Strategy

Apply the steps for drawing a Lewis structure.

Act on Your Strategy

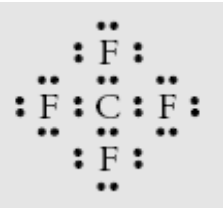
Step 1. The total number of valence electrons in the molecule is

$$(1\ \text{C atom} \times \frac{4\ e^-}{\text{C atom}}) + (4\ \text{F atoms} \times \frac{7\ e^-}{\text{F atom}}) = 32\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Carbon has four unpaired electrons and each fluorine has one unpaired electron. Therefore carbon is the central atom. Draw a skeleton structure with one pair of bonding electrons between each fluorine atom and the central carbon atom.

Step 3. Place lone pairs around the fluorine atoms to form octets. The skeleton structure has 32 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.

CF_4



Check Your Solution

The carbon and fluorine atoms each have eight valence electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

10.

Problem

Draw a Lewis structure for $AsH_3(g)$

What is Required?

You must draw the Lewis structure for $AsH_3(g)$.

What is Given?
The chemical formula, $AsH_3(g)$, tells you that there are three hydrogen atoms and one arsenic atom in this molecule.

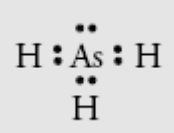
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(1\ \text{As atom} \times \frac{5\,e^-}{\text{As atom}}) + (3\ \text{H atoms} \times \frac{1\,e^-}{\text{H atom}}) = 8\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Arsenic has three unpaired electrons and each hydrogen atom has one unpaired electron. Therefore, arsenic is the central atom. Draw a skeleton structure with one pair of bonding electrons between each hydrogen atom and the central arsenic atom.
Step 3. Place a lone pair around the arsenic atom to form an octet. The skeleton structure has eight electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.

AsH_3



Check Your Solution
The arsenic atom has eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

11.
Problem
Draw the Lewis structure for $H_2S(g)$.

What is Required?
You must draw the Lewis structure for $H_2S(g)$.

What is Given?
The chemical formula, $H_2S(g)$, tells you that there are two hydrogen atoms and one sulfur atom in this molecule.

Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy

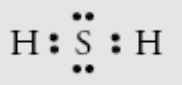
Step 1. The total number of valence electrons in the molecule is

$$(1\ \text{S atom} \times \frac{6\ e^-}{\text{S atom}}) + (2\ \text{H atoms} \times \frac{1\ e^-}{\text{H atom}}) = 8\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Sulfur has two unpaired electrons and each hydrogen atom has one unpaired electron. Therefore, sulfur is the central atom. Draw a skeleton structure with one pair of bonding electrons between each hydrogen atom and the central sulfur atom.

Step 3. Place two lone pairs of electrons around the sulfur atom to form an octet. The skeleton structure has eight electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.

H_2S



Check Your Solution

The sulfur atom has eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

12.

Problem

Draw the Lewis structure for $H_2O_2(\ell)$.

What is Required?

You must draw the Lewis structure for $H_2O_2(\ell)$.

What is Given?

The chemical formula, $H_2O_2(\ell)$, tells you that there are two hydrogen atoms and two oxygen atoms in this molecule.

Plan Your Strategy

Apply the steps for drawing a Lewis structure.

Act on Your Strategy

Step 1. The total number of valence electrons in the molecule is

$$(2\ \text{O atoms} \times \frac{6\ e^-}{\text{O atom}}) + (2\ \text{H atoms} \times \frac{1\ e^-}{\text{H atom}}) = 14\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Oxygen has two unpaired electrons and hydrogen has one unpaired electron. Since each oxygen atom is the same, it is reasonable to assume that the two oxygen atoms attract the hydrogen atoms equally and, therefore, one hydrogen atom is bonded to each oxygen atom. Draw a skeleton structure with one pair of bonding electrons between the two oxygen atoms. Draw one pair of bonding electrons between each hydrogen atom and each oxygen atom separately.

Step 3. Place two lone pairs of electrons around each oxygen atoms to form an octet. The skeleton structure has 14 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.

H_2O_2

Check Your Solution
The oxygen atom has eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

13.
Problem
Draw the Lewis structure for ClNO(g).

What is Required?
You must draw the Lewis structure for ClNO(g).

What is Given?
The chemical formula, ClNO(g), tells you that there is one chlorine atom, one nitrogen atom, and one oxygen atom in this molecule.

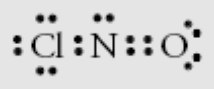
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(1\ \text{Cl atom} \times \frac{7\ e^-}{\text{Cl atom}}) + (1\ \text{N atom} \times \frac{5\ e^-}{\text{N atom}}) + (1\ \text{O atom} \times \frac{6\ e^-}{\text{O atom}}) = 18\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Nitrogen has three unpaired electrons, oxygen has two unpaired electrons, and hydrogen has one unpaired electron. Therefore, nitrogen is the central atom. Draw a skeleton structure with one pair of bonding electrons between the chlorine atom and the nitrogen atom. Draw one pair of bonding electrons between the oxygen atom and the nitrogen atom.
Step 3. Place pairs of electrons around the chlorine and oxygen atoms (not the central nitrogen atom) to form octets. There are now 16 valence electrons used for this structure.
Step 4. Since two of the valence electrons from Step 1 are not accounted for, add a pair of electrons around the central nitrogen atom. Since the nitrogen atom has only six valence electrons, move a lone pair of electrons from the oxygen to the nitrogen to form a double bond between the nitrogen atom and the oxygen atom.

ClNO



Check Your Solution
The nitrogen, chlorine, and oxygen atoms all have eight valence electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

14.
Problem
Draw the Lewis structure for $C_2H_4(g)$.

What is Required?
You must draw the Lewis structure for $C_2H_4(g)$.

What is Given?
The chemical formula, $C_2H_4(g)$, tells you that there are two carbon atoms and four hydrogen atoms in this molecule.

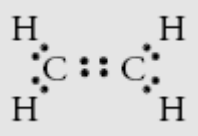
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(2\text{ C atoms} \times \frac{4\,e^-}{\text{C atom}}) + (4\text{ H atoms} \times \frac{1\,e^-}{\text{H atom}}) = 12\,e^-$$

Step 2. Select the atom with the most unpaired electrons. Carbon has four unpaired electrons and hydrogen has one unpaired electron. Since each carbon atom is the same, it is reasonable to assume that the two carbon atoms attract the hydrogen atoms equally and, therefore, two hydrogen atoms are bonded to each carbon. Draw a skeleton structure with one pair of bonding electrons between the two carbon atoms and one pair of bonding electrons between each hydrogen atom and a carbon atom.
Step 3. The skeletal structure has 12 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.
Step 4. The carbon atoms have only seven valence electrons. Therefore, share the unpaired electron from each carbon atom to form a double bond.

C_2H_4



Check Your Solution
Each carbon atom has eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

15.
Problem
Draw a Lewis structure for $CS_2(\ell)$.

What is Required?
You must draw the Lewis structure for $CS_2(\ell)$.

What is Given?
The chemical formula, $CS_2(\ell)$, tells you that there is one carbon atom and two sulfur atoms in this molecule.

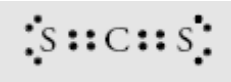
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(1\text{ C atom} \times \frac{4\,e^-}{\text{C atom}}) + (2\text{ S atoms} \times \frac{6\,e^-}{\text{S atom}}) = 16\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Carbon has four unpaired electrons and sulfur has two unpaired electrons. Therefore, carbon is the central atom. Draw a skeleton structure with one pair of bonding electrons between the carbon atom and each sulfur atom.
Step 3. Place three lone pairs of electrons around each sulfur atom to form an octet. The skeleton structure now has 16 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.
Step 4. The carbon atom has only six valence electrons. Therefore, share a lone pair of electrons from each sulfur atom to form a double bond between the carbon and each sulfur atom.

CS_2



Check Your Solution
The carbon and sulfur atoms have eight valence electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

16.
Problem
Draw the Lewis structure for HOCl(g).

What is Required?
You must draw the Lewis structure for HOCl(g).

What is Given?
The chemical formula, HOCl(g), tells you that there is one hydrogen atom, one oxygen atom, and one chlorine atom in this molecule.

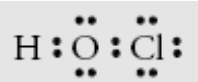
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(1\ \text{H atom} \times \frac{1e^-}{\text{H atom}}) + (1\ \text{O atom} \times \frac{6\ e^-}{\text{O atom}}) + (1\ \text{Cl atom} \times \frac{7e^-}{\text{Cl atom}}) = 14\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Oxygen has two unpaired electrons, chlorine has one unpaired electron, and hydrogen has one unpaired electron. Therefore, oxygen is the central atom. Draw a skeleton structure with one pair of bonding electrons between the oxygen and chlorine atoms, and one pair of bonding electrons between the oxygen and hydrogen atoms.
Step 3. Place three lone pairs around the chlorine atom to form an octet. There are now 10 valence electrons used for this structure.
Step 4. Since four of the valence electrons from Step 1 are not accounted for, add two lone pairs of electrons around the central oxygen atom. The skeleton structure has 14 electrons, which is the same as the total number of valence electrons in step 1. The number of electrons is correct.

HOCl



Check Your Solution
The chlorine and oxygen atoms have 8 valence electrons and the hydrogen atom has 2 valence electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

17.
Problem
Draw a Lewis structure for $C_2H_2(g)$.

What is Required?
You must draw the Lewis structure for $C_2H_2(g)$.

What is Given?
The chemical formula, $C_2H_2(g)$, tells you that there are two carbon atoms and two hydrogen atoms in this molecule.

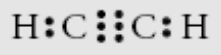
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(2\text{ C atoms} \times \frac{4\,e^-}{\text{C atom}}) + (2\text{ H atoms} \times \frac{1\,e^-}{\text{H atom}}) = 10\,e^-$$

Step 2. Select the atom with the most unpaired electrons. Carbon has four unpaired electrons and hydrogen has one unpaired electron. Since each carbon atom is the same, it is reasonable to assume that the two carbon atoms attract the hydrogen atoms equally and, therefore, one hydrogen atom is bonded to each carbon. Draw a skeleton structure with one pair of bonding electrons between the two carbon atoms and one pair of bonding electrons between each hydrogen atom and a carbon atom.
Step 3. The skeletal structure has six electrons. There are four electrons from Step 1 that are not accounted for. Therefore, add two electrons to each carbon.
Step 4. The carbon atoms have only six valence electrons. Therefore, share the two unpaired electrons from each carbon atom to form a triple bond. The structure has 10 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.

C_2H_2



Check Your Solution
Each carbon atom has eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

18.
Problem
Draw the Lewis structure for the $BrO^-(aq)$ ion.

What is Required?
You must draw the Lewis structure for $BrO^-(aq)$.

What is Given?
The chemical formula $BrO^-(aq)$ tells you that the hypobromite ion has one bromine atom, and one oxygen atom, and carries a charge of 1–.

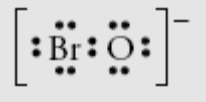
Plan Your Strategy
Follow the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. Determine the total number of valence electrons in all of the atoms. Add one electron for the charge of 1–.

$$(1\text{ Br atom} \times \frac{7\,e^-}{\text{Br atom}}) + (1\text{ O atom} \times \frac{6\,e^-}{\text{O atom}}) + 1\,e^- = 14\,e^-$$

Step 2. Note which atom has fewer unpaired electrons. The bromine has one unpaired electron and the oxygen atom has two unpaired electrons. Since this is a diatomic ion, there is no central atom. Draw a skeleton structure of the ion with one pair of bonding electrons between the bromine and oxygen atoms.
Step 3. Place three lone pairs around the bromine atom to form an octet. There are now eight valence electrons used for this structure.
Step 4. Since six of the valence electrons from Step 1 are not accounted for, add three lone pairs of electrons around the oxygen atom. The skeleton structure has 14 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct. Show the charge of 1– on the ion.

BrO^-



Check Your Solution
Both the bromine and oxygen atoms have eight valence electrons. Since each atom has achieved a noble gas electron configuration and the correct charge on the ion is shown, this is a reasonable Lewis structure.

19.
Problem
Draw the Lewis structure for the $NO^+(aq)$ ion.

What is Required?
You must draw the Lewis structure for $NO^+(aq)$.

What is Given?
The chemical formula $NO^+(aq)$ tells you that this ion has one nitrogen atom and one oxygen atom, and carries a charge of 1+.

Plan Your Strategy
Follow the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. Determine the total number of valence electrons in all of the atoms. Subtract 1 electron for the charge of 1+.

$$(1\ \text{N atom} \times \frac{5\,e^-}{\text{N atom}}) + (1\ \text{O atom} \times \frac{6\,e^-}{\text{O atom}}) - 1\ e^- = 10\ e^-$$

Step 2. Note which atom has fewer unpaired electrons. The nitrogen has three unpaired electrons and the oxygen atom has two unpaired electrons. Since this is a diatomic ion, there is no central atom. Draw a skeletal structure of the ion with one pair of bonding electrons between the nitrogen and oxygen atoms.

Step 3. Place lone pairs around the oxygen atom to form an octet. There are now eight valence electrons used for this structure.
Step 4. Since two of the valence electrons from step 1 are not accounted for, add one lone pair of electrons around the nitrogen atom. Since the nitrogen atom has only four valence electrons, move two lone pairs of electrons from the oxygen atom to form a triple bond. There are two co-ordinate covalent bonds in this structure. The skeleton structure has 10 electrons which is the same as the total number of valence electrons in Step1. The number of electrons is correct. Show the 1+ charge on the ion.

NO^+

Check Your Solution
Both the nitrogen and oxygen atoms have eight valence electrons. Since each atom has achieved a noble gas electron configuration and the correct charge on the ion is shown, this is a reasonable Lewis structure.

20.
Problem
Draw the Lewis structure for $ClO_3^-(aq)$.

What is Required?
You must draw the Lewis structure for $ClO_3^-(aq)$.

What is Given?
The chemical formula, $ClO_3^-(aq)$, tells you that there is one chlorine atom and three oxygen atoms, and a charge of 1– on this ion.

Plan Your Strategy
Apply the steps for drawing a Lewis structure.

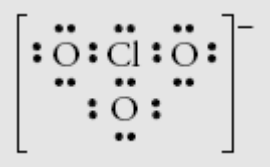
Act on Your Strategy
Step 1. Determine the total number of valence electrons in all of the atoms. Add 1 electron for the charge of 1–.

$$(1\ \text{Cl atom} \times \frac{7\ e^-}{\text{Cl atom}}) + (3\ \text{O atom} \times \frac{6\ e^-}{\text{O atom}}) + 1\ e^- = 26\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Chlorine has one unpaired electron and oxygen has two unpaired electrons. Since all three oxygen atoms are equivalent, it is not likely that one would be the central atom over another. Therefore, make the assumption that the chlorine atom will be the central atom (even though it has fewer unpaired electrons). Draw a skeleton structure with one pair of bonding electrons between the chlorine and each oxygen atom.

Step 3. Place lone pairs around the oxygen atoms to form octets. There are now 24 valence electrons used for this structure.
Step 4. Since two of the valence electrons from Step 1 are not accounted for, add a lone pair of electrons around the central chlorine atom. Indicate the charge of 1– on the ion.

ClO_3^-



Check Your Solution
The chlorine and oxygen atoms have eight valence electrons. Since each atom has achieved a noble gas electron configuration and the correct charge is shown on the ion, this is a reasonable Lewis structure.

21.
Problem
Draw the Lewis structure for the $SO_3^{2-}(aq)$ ion.

What is Required?
You must draw the Lewis structure for $SO_3^{2-}(aq)$.

What is Given?
The chemical formula $SO_3^{2-}(aq)$ tells you that the sulfite ion has one sulfur atom and three oxygen atoms, and carries a charge of 2–.

Plan Your Strategy
Follow the steps for drawing a Lewis structure.

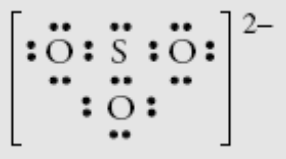
Act on Your Strategy
Step 1. Determine the total number of valence electrons in all of the atoms. Add two electrons for the charge of 2–.

$$(1\text{ S atom} \times \frac{6\,e^-}{\text{S atom}}) + (3\text{ O atoms} \times \frac{6\,e^-}{\text{O atom}}) + 2\,e^- = 26\,e^-$$

Step 2. Select the atom with the most unpaired electrons. The sulfur and oxygen atoms have two unpaired electrons. It is reasonable to assume that the sulfur atom will be the central atom since all three oxygen atoms are equivalent. Draw a skeleton structure of the ion with one pair of bonding electrons between the sulfur atom and each of the oxygen atoms.
Step 3. Place lone pairs of electrons around the oxygen atoms to form octets. There are now 24 valence electrons used for this structure. Each oxygen atom has eight valence electrons but the sulfur atom has only six valence electrons.

Step 4. Since two of the valence electrons from Step 1 are not accounted for, add a lone pair of electrons around the central sulfur atom. The number of electrons is correct. Show the charge of 2– on the ion.

SO_3^{2-}



Check Your Solution
The sulfur and the three oxygen atoms each have eight valence electrons. Since each atom has achieved a noble gas electron configuration and the correct charge on the ion is shown, this is a reasonable Lewis structure.

22.
Problem
Dichlorofluoroethane, $CH_3CFCl_2(g)$, has been proposed as a replacement for chlorofluorocarbons (CFCs). The presence of the hydrogen atoms in $CH_3CFCl_2(g)$ markedly reduces the ozone-depleting ability of the compound. Draw a Lewis structure for this molecule.

What is Required?
You must draw the Lewis structure for $CH_3CFCl_2(g)$.

What is Given?
The chemical formula, $CH_3CFCl_2(g)$ tells you that there are two carbon atoms, three hydrogen atoms, one fluorine atom, and two chlorine atoms in this molecule.

Plan Your Strategy
Apply the steps for drawing a Lewis structure.

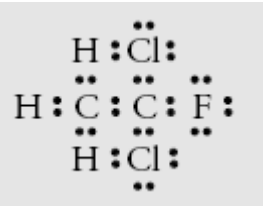
Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(2\text{ C atoms} \times \frac{4\,e^-}{\text{C atom}}) + (3\text{ H atoms} \times \frac{1\,e^-}{\text{H atom}}) + (1\text{ F atom} \times \frac{7\,e^-}{\text{F atom}}) + (2\text{ Cl atoms} \times \frac{7\,e^-}{\text{Cl atom}}) = 32\ e^-$$

Step 2. The manner in which the chemical formula is written, CH_3CFCl_2, indicates that three hydrogen atoms are bonded to one carbon and the fluorine atom and two chlorine atoms are bonded to the second carbon atom. Draw a skeleton structure with one pair of bonding electrons between a carbon atom and each of the three hydrogen atoms, one pair of bonding electrons between the two carbon atoms, and one pair of bonding electrons between the second carbon atom and each of the fluorine and three chlorine atoms.

Step 3. Each hydrogen has two electrons and will not have any lone pairs of electrons. Add lone pairs of electrons to the fluorine and chlorine atoms to form octets. The skeleton structure now has 32 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.

CH_3CFCl_2



Check Your Solution
Each carbon atom, the fluorine atom, and each of the chlorine atoms have eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this Lewis structure is reasonable.

23. a)
Problem
Draw a Lewis structure for $N_2H_4(g)$. It does not have a single central atom.

What is Required?
You must draw the Lewis structure for $N_2H_4(g)$.

What is Given?
The chemical formula, $N_2H_4(g)$, tells you that there are two nitrogen atoms and four hydrogen atoms in this molecule.

Plan Your Strategy
Apply the steps for drawing a Lewis structure.

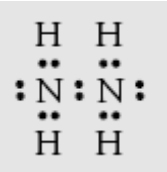
Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(2\text{ N atoms} \times \frac{5\text{e}^-}{\text{N atom}}) + (4\text{ H atoms} \times \frac{1\text{ e}^-}{\text{H atom}}) = 14\text{ e}^-$$

Step 2. Select the atom with the most unpaired electrons. Nitrogen has three unpaired electrons and hydrogen has one unpaired electron. The two nitrogen atoms attract the hydrogen atoms equally. Therefore, two hydrogen atoms are bonded to each nitrogen atom. Draw a skeleton structure with one pair of bonding electrons between the two nitrogen atoms and one pair of bonding electrons between each hydrogen atom and a separate nitrogen atom. This skeleton structure uses 10 electrons.
Step 3. Since four electrons from Step 1 are not accounted for, add a lone pair of electrons to each nitrogen atom. No lone pairs of electrons are found around the hydrogen atoms. The

skeleton structure now has 14 electrons, which is the same as the total number of valence electrons in Step 1. The number of electrons is correct.

N_2H_4



Check Your Solution
The nitrogen atoms have eight valence electrons and each hydrogen atom has two electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

23. b)
Problem
Draw the Lewis structure for $N_2F_2(g)$. It does not have a single central atom.

What is Required?
You must draw the Lewis structure for $N_2F_2(g)$.

What is Given?
The chemical formula, $N_2F_2(g)$, tells you that there are two nitrogen atoms and two fluorine atoms in this molecule.

Plan Your Strategy
Apply the steps for drawing a Lewis structure.

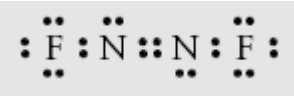
Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(2\text{ N atoms} \times \frac{5e^-}{\text{N atom}}) + (2\text{ F atoms} \times \frac{7\ e^-}{\text{F atom}}) = 24\ e^-$$

Step 2. Select the atom with the most unpaired electrons. Nitrogen has three unpaired electrons and hydrogen has one unpaired electron. One fluorine atom is bonded to each nitrogen atom. Draw a skeleton structure with one pair of bonding electrons between the two nitrogen atoms, and one pair of bonding electrons between each fluorine atom and a separate nitrogen atom.
Step 3. Place lone pairs around each fluorine atom to form octets. There are now 18 valence electrons used for this structure. Each fluorine atom has eight valence electrons but the two nitrogen atoms each have only four valence electrons.
Step 4. Add two lone pairs of electrons around each nitrogen atom. Each nitrogen atom now has eight valence electrons, but the total number of electrons in the skeleton structure is 26, which is two more than in Step 1..

Step 5. Share a lone pair from each of the nitrogen atoms to form a double bond between the two nitrogens. The number of electrons is now correct. The skeleton structure has 24 electrons, which is the same as the total number of valence electrons in Step 1.

N_2F_2



Check Your Solution
The nitrogen and fluorine atoms have eight valence electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.

24.
Problem
Although Group 18 elements are never found in compounds in nature, chemists are able to synthesize compounds of several noble gases, including xenon, Xe(g). Draw a Lewis structure for the xenon tetroxide, XeO_4(aq), molecule.

What is Required?
You must draw the Lewis structure for XeO_4(aq).

What is Given?
The chemical formula, XeO_4(aq), tells you that there are four oxygen atoms and one xenon atom in this molecule.

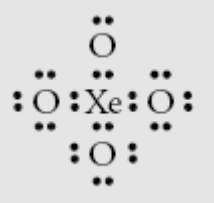
Plan Your Strategy
Apply the steps for drawing a Lewis structure.

Act on Your Strategy
Step 1. The total number of valence electrons in the molecule is

$$(1\ \text{Xe atom} \times \frac{8\,e^-}{\text{Xe atom}}) + (4\ \text{O atoms} \times \frac{6\ e^-}{\text{O atom}}) = 32\ e^-$$

Step 2. Even though xenon has no unshared electrons, it must be the central atom, because the four oxygen atoms are equivalent and there is no reason for one to be a central atom over another. Also, since the xenon atom has eight valence electrons, it cannot share an electron in a bonding pair without exceeding this octet.
Step 3. Since each oxygen atom has six valence electrons and needs to gain two more for an octet, the xenon atom will share a pair of its electrons with each oxygen atom as a coordinate covalent bond.

XeO_4



Check Your Solution
The xenon and oxygen atoms have eight valence electrons. Since each atom has achieved a noble gas electron configuration, this is a reasonable Lewis structure.