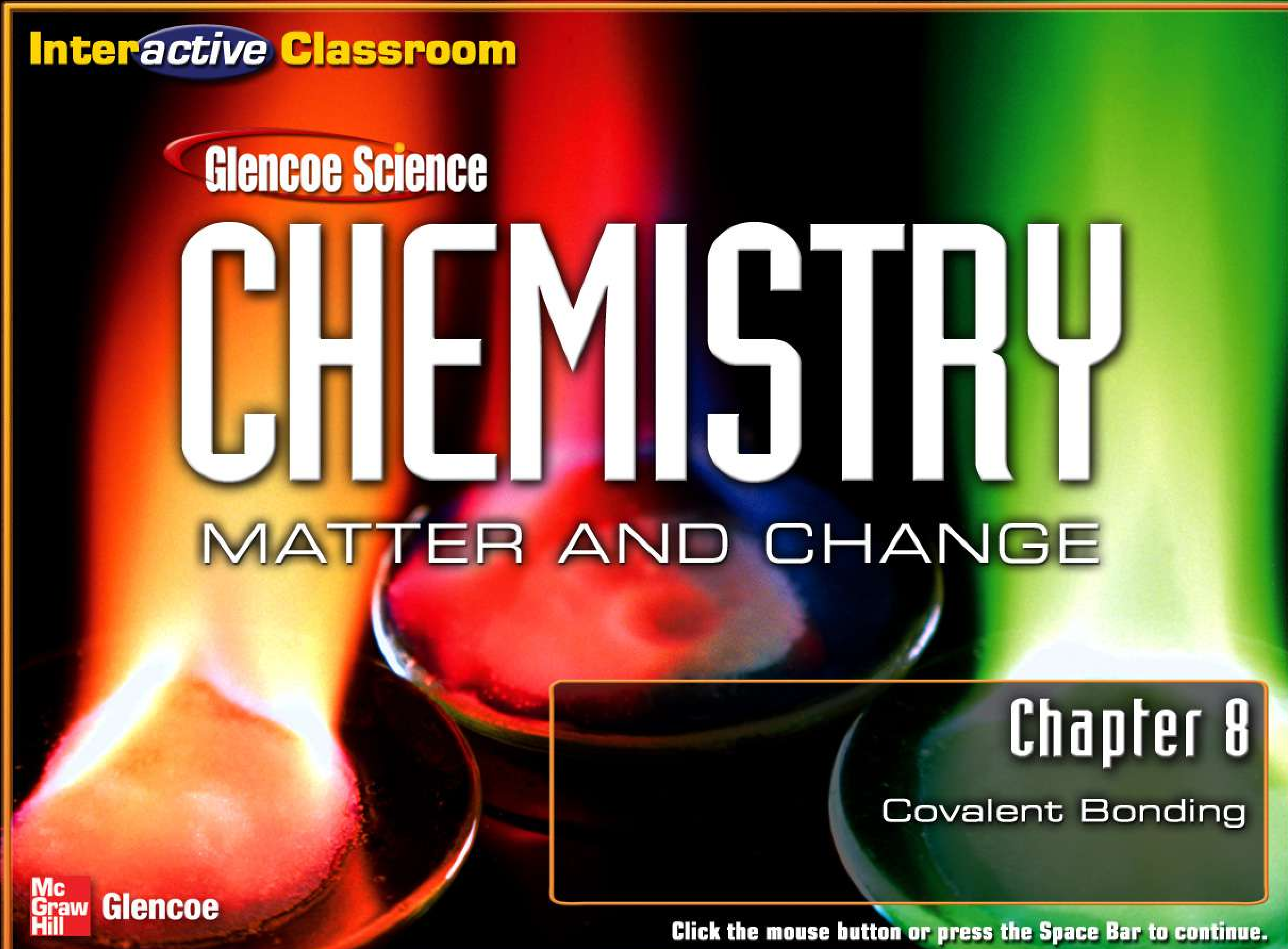

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Covalent Bonding

Click a hyperlink or folder tab to view the corresponding slides.

Section 8.1 The Covalent Bond

Objectives

- **Apply** the octet rule to atoms that form covalent bonds.
- **Describe** the formation of single, double, and triple covalent bonds.
- **Contrast** sigma and pi bonds.
- **Relate** the strength of a covalent bond to its bond length and bond dissociation energy.

Review Vocabulary

chemical bond: the force that holds two atoms together

Section 8.1 The Covalent Bond (cont.)

New Vocabulary

covalent bond

molecule

Lewis structure

sigma bond

pi bond

endothermic reaction

exothermic reaction

MAIN Idea **Atoms gain stability when they share electrons and form covalent bonds.**

Why do atoms bond?

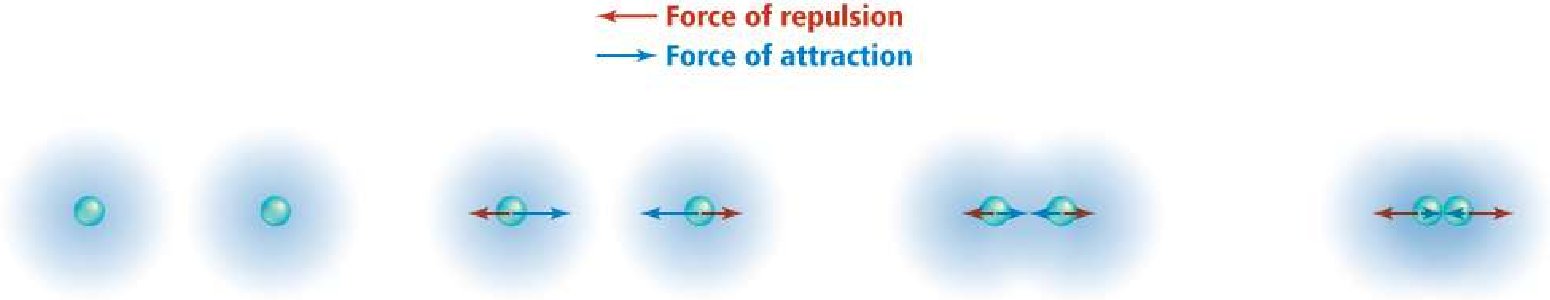
- Atoms gain stability when they share electrons and form covalent bonds.
- Lower energy states make an atom more stable.
- Gaining or losing electrons makes atoms more stable by forming ions with noble-gas electron configurations.
- Sharing valence electrons with other atoms also results in noble-gas electron configurations.

Why do atoms bond? (cont.)

- Atoms in non-ionic compounds share electrons.
- The chemical bond that results from sharing electrons is a **covalent bond**.
- A **molecule** is formed when two or more atoms bond.

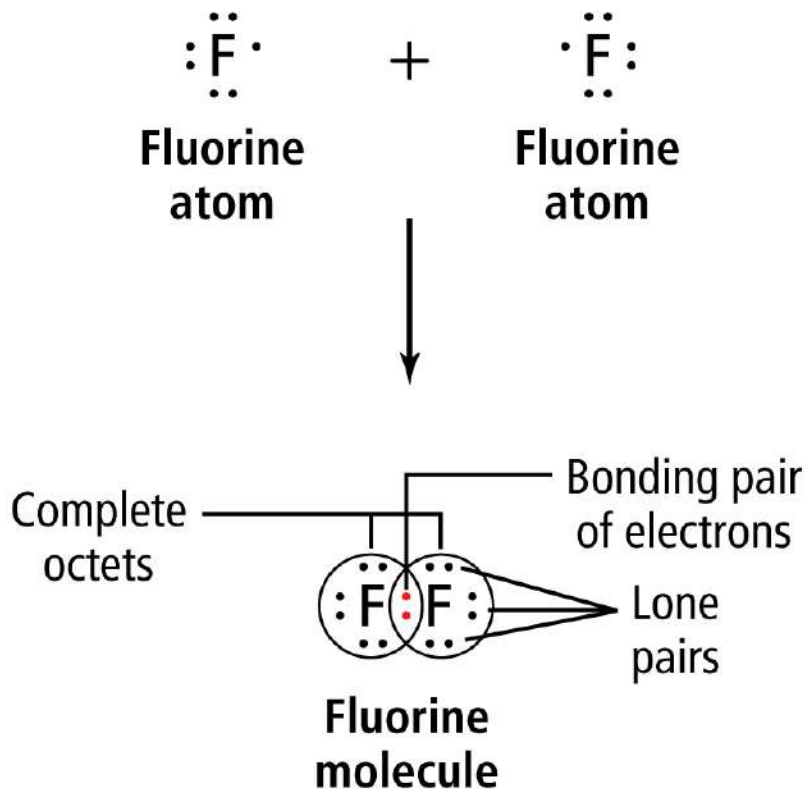
Why do atoms bond? (cont.)

- Diatomic molecules (H_2, F_2 for example) exist because two-atom molecules are more stable than single atoms.



Why do atoms bond? (cont.)

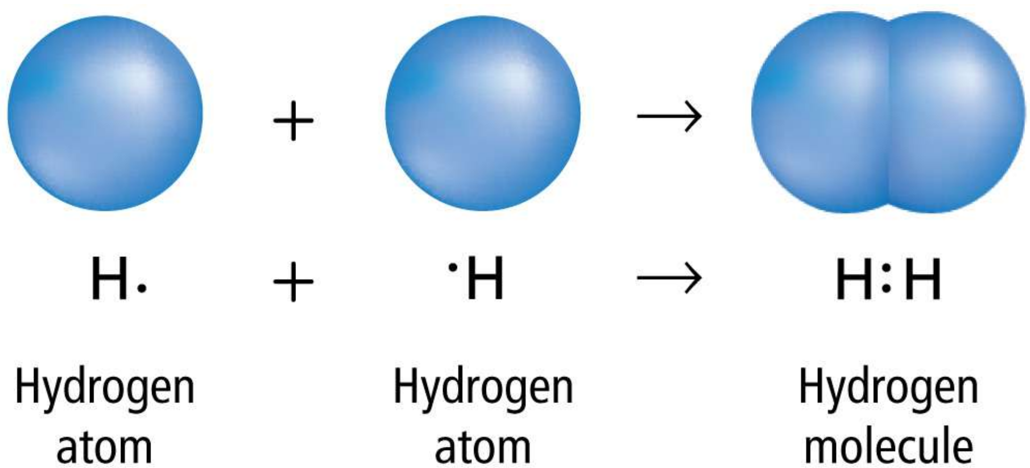
- The most stable arrangement of atoms exists at the point of maximum net attraction, where the atoms bond covalently and form a molecule.



Single Covalent Bonds

- When only one pair of electrons is shared, the result is a single covalent bond.

- The figure shows two hydrogen atoms forming a hydrogen molecule with a single covalent bond, resulting in an electron configuration like helium.



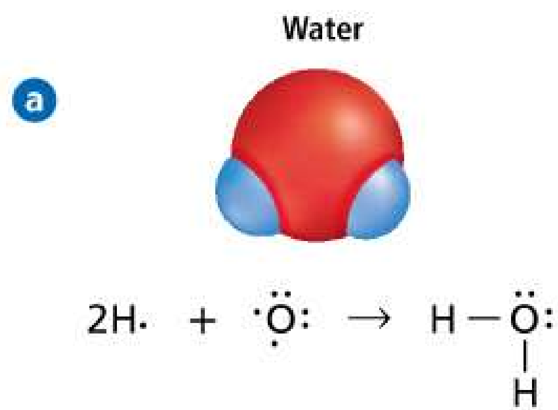
Single Covalent Bonds (cont.)

- In a **Lewis structure** dots or a line are used to symbolize a single covalent bond.
- The halogens—the group 17 elements—have 7 valence electrons and form single covalent bonds with atoms of other non-metals.

Single Covalent Bonds (cont.)

- Atoms in group 16 can share two electrons and form two covalent bonds.

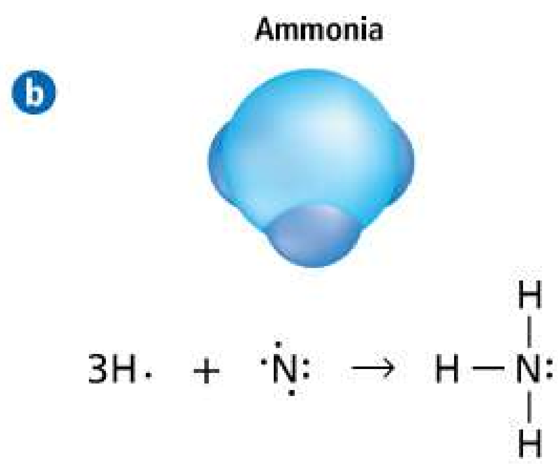
- Water is formed from one oxygen with two hydrogen atoms covalently bonded to it .



Two Single Covalent Bonds

Single Covalent Bonds (cont.)

- Atoms in group 15 form three single covalent bonds, such as in ammonia.

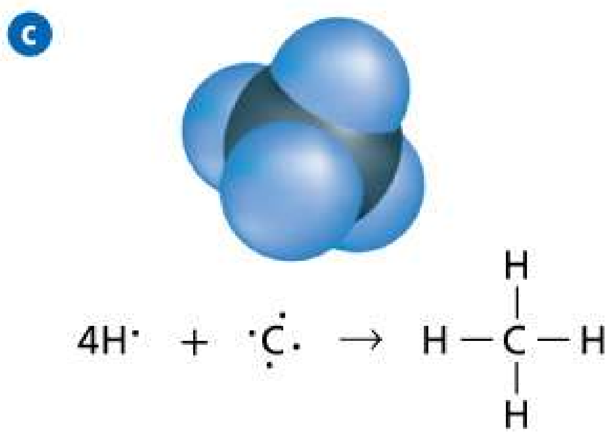


Three Single Covalent Bonds

Single Covalent Bonds (cont.)

- Atoms of group 14 elements form four single covalent bonds, such as in methane.

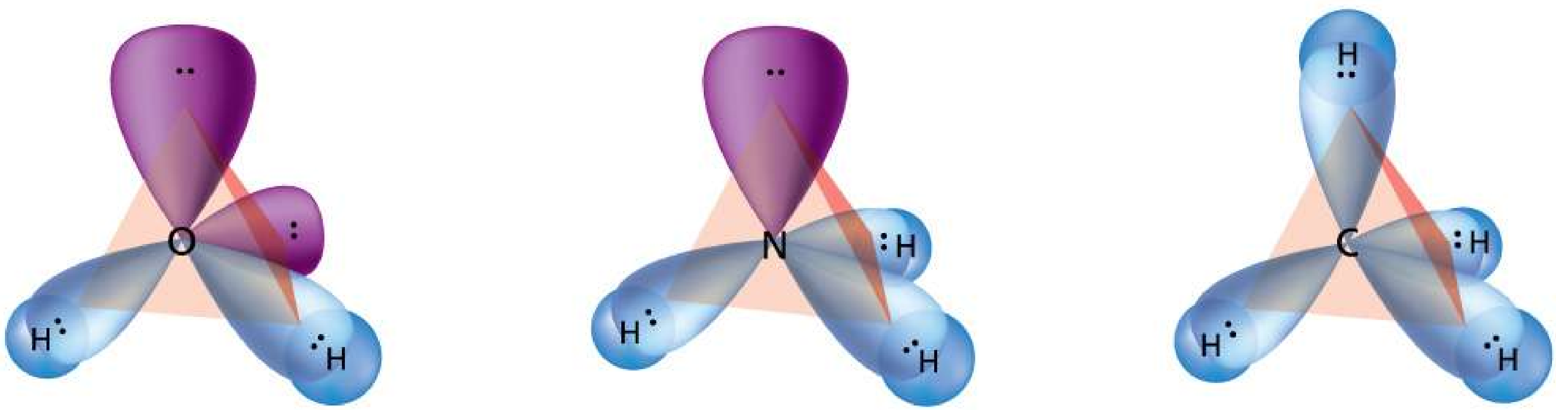
Methane



Four Single Covalent Bonds

Single Covalent Bonds (cont.)

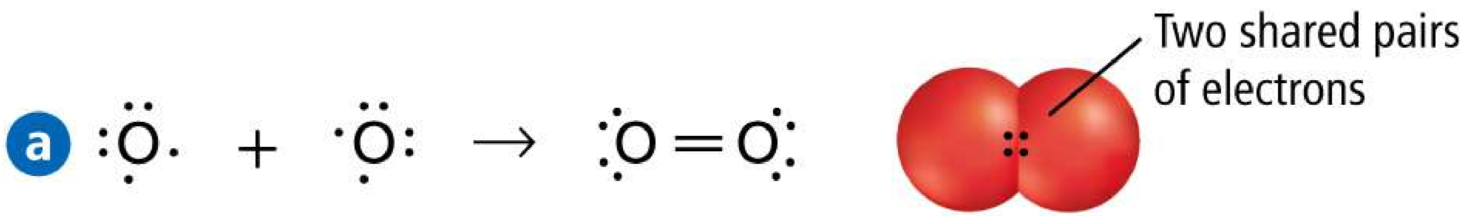
- **Sigma bonds** are single covalent bonds.
- Sigma bonds occur when the pair of shared electrons is in an area centered between the two atoms.



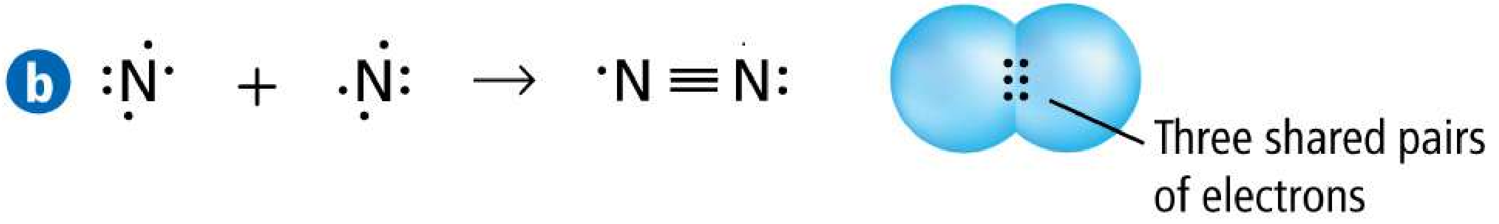
Water (H_2O) Ammonia (NH_3) Methane (CH_4)

Multiple Covalent Bonds

- Double bonds form when two pairs of electrons are shared between two atoms.

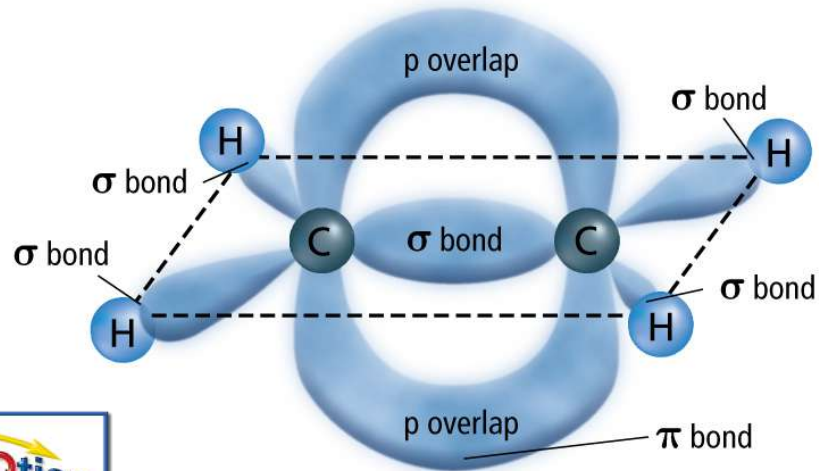


- Triple bonds form when three pairs of electrons are shared between two atoms.

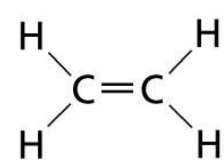


Multiple Covalent Bonds (cont.)

- A multiple covalent bond consists of one sigma bond and at least one pi bond.
- The **pi bond** is formed when parallel orbitals overlap and share electrons.



Ethene



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The Strength of Covalent Bonds

- The strength depends on the distance between the two nuclei, or bond length.
- As length increases, strength decreases.

Table 8.1 Covalent Bond Type and Bond Length

Molecule	Bond Type	Bond Length
F_2	single covalent	1.43×10^{-10} m
O_2	double covalent	1.21×10^{-10} m
N_2	triple covalent	1.10×10^{-10} m

The Strength of Covalent Bonds (cont.)

- The amount of energy required to break a bond is called the bond dissociation energy.
- The shorter the bond length, the greater the energy required to break it.

Table 8.2 Bond-Dissociation Energy

Molecule	Bond-Dissociation Energy
F_2	159 kJ/mol
O_2	498 kJ/mol
N_2	945 kJ/mol

The Strength of Covalent Bonds (cont.)

- An **endothermic reaction** is one where a greater amount of energy is required to break a bond in reactants than is released when the new bonds form in the products.
- An **exothermic reaction** is one where more energy is released than is required to break the bonds in the initial reactants.

CheckPoint

Section 8.1 Assessment

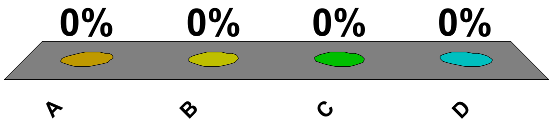
What does a triple bond consists of?

A. three sigma bonds

B. three pi bonds

C. two sigma bonds and one pi bond

D. two pi bonds and one sigma bond



CheckPoint

Section 8.1 Assessment

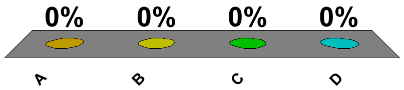
Covalent bonds are different from ionic bonds because:

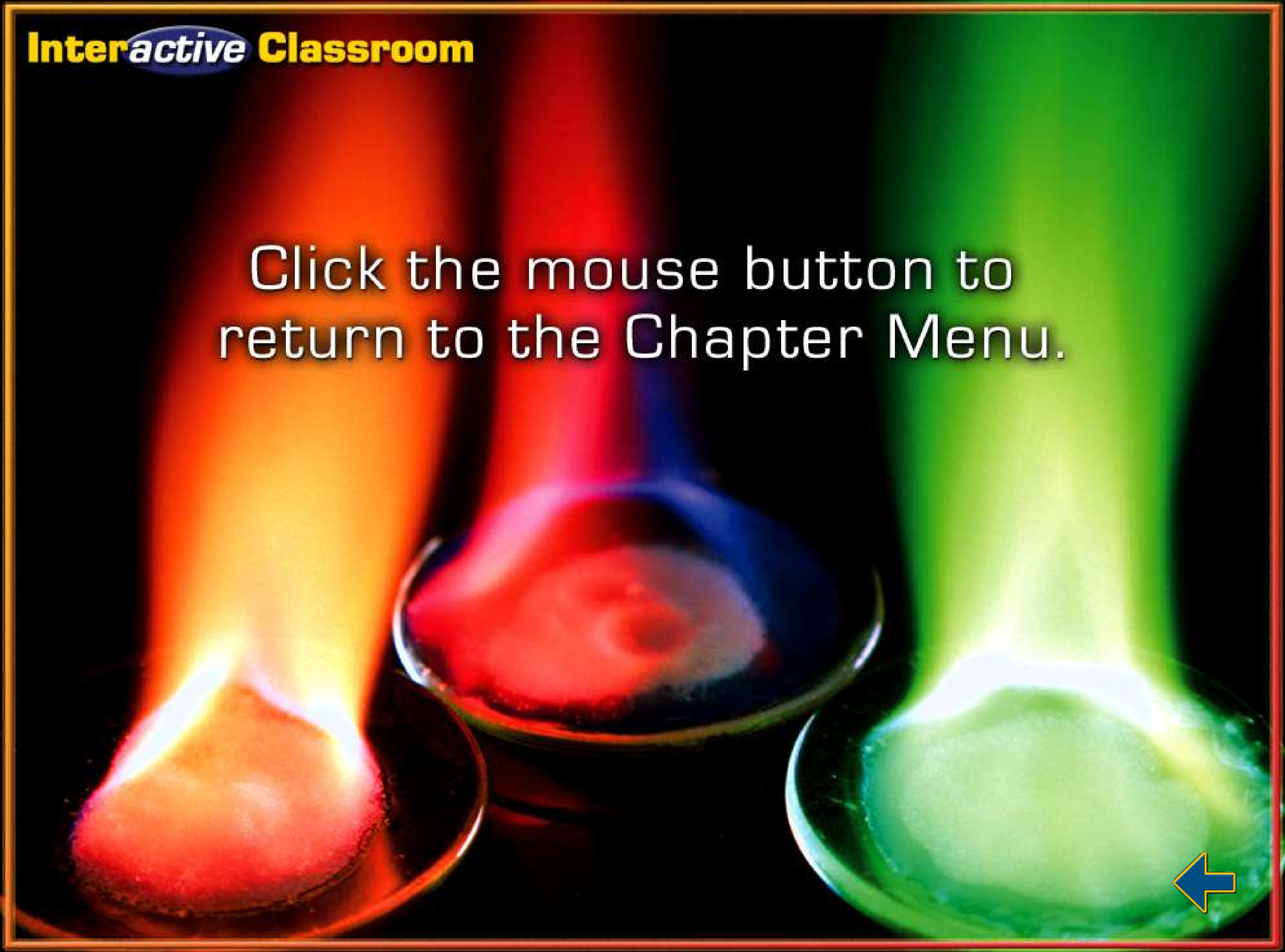
A. atoms in a covalent bond lose electrons to another atom

B. atoms in a covalent bond do not have noble-gas electron configurations

C. atoms in a covalent bond share electrons with another atom

D. atoms in covalent bonds gain electrons from another atom

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Section 8.2 Naming Molecules

Objectives

- **Translate** molecular formulas into binary molecular compound names.
- **Name** acidic solutions.

Review Vocabulary

oxyanion: a polyatomic ion in which an element (usually a nonmetal) is bonded to one or more oxygen atoms

New Vocabulary

oxyacid

MAIN Idea **Specific rules are used when naming binary molecular compounds, binary acids, and oxyacids.**

Naming Binary Molecular Compounds

- The first element is always named first using the entire element name.
- The second element is named using its root and adding the suffix *–ide*.

Naming Binary Molecular Compounds (cont.)

- Prefixes are used to indicate the number of atoms of each element in a compound.

Table 8.3 Prefixes in Covalent Compounds

Number of Atoms	Prefix	Number of Atoms	Prefix
1	mono-	6	hexa-
2	di-	7	hepta-
3	tri-	8	octa-
4	tetra-	9	nona-
5	penta-	10	deca-

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Naming Binary Molecular Compounds (cont.)

- Many compounds were discovered and given common names long before the present naming system was developed (water, ammonia, hydrazine, nitric oxide).

Naming Acids

- The first word has the prefix *hydro-* followed by the root of the element plus the suffix *–ic*.
- The second word is always acid (hydrochloric acid is HCl in water).

Naming Acids (cont.)

- An **oxyacid** is an acid that contains both a hydrogen atom and an oxyanion.
- Identify the oxyanion present.
- The first word is the root of the oxyanion and the prefix *per-* or *hypo-* if it is part of the name, plus the suffix -*ic* if the anion ends in *-ate* or *-ous* if the oxyanion ends in *-ite*.

Naming Acids (cont.)

- The second word is always acid.

Table 8.4 Naming Oxyacids

Compound	Oxyanion	Acid Suffix	Acid Name
$HClO_3$	chlorate	-ic	chloric acid
$HClO_2$	chlorite	-ous	chlorous acid
HNO_3	nitrate	-ic	nitric acid
HNO_2	nitrite	-ous	nitrous acid

Naming Acids (cont.)

- An acid, whether a binary acid or an oxyacid, can have a common name in addition to its compound name.

Table 8.5 Formulas and Names of Some Covalent Compounds

Formula	Common Name	Molecular Compound Name
H_2O	water	dihydrogen monoxide
NH_3	ammonia	nitrogen trihydride
N_2H_4	hydrazine	dinitrogen tetrahydride
HCl	muriatic acid	hydrochloric acid
$C_9H_8O_4$	aspirin	2-(acetyloxy)benzoic acid

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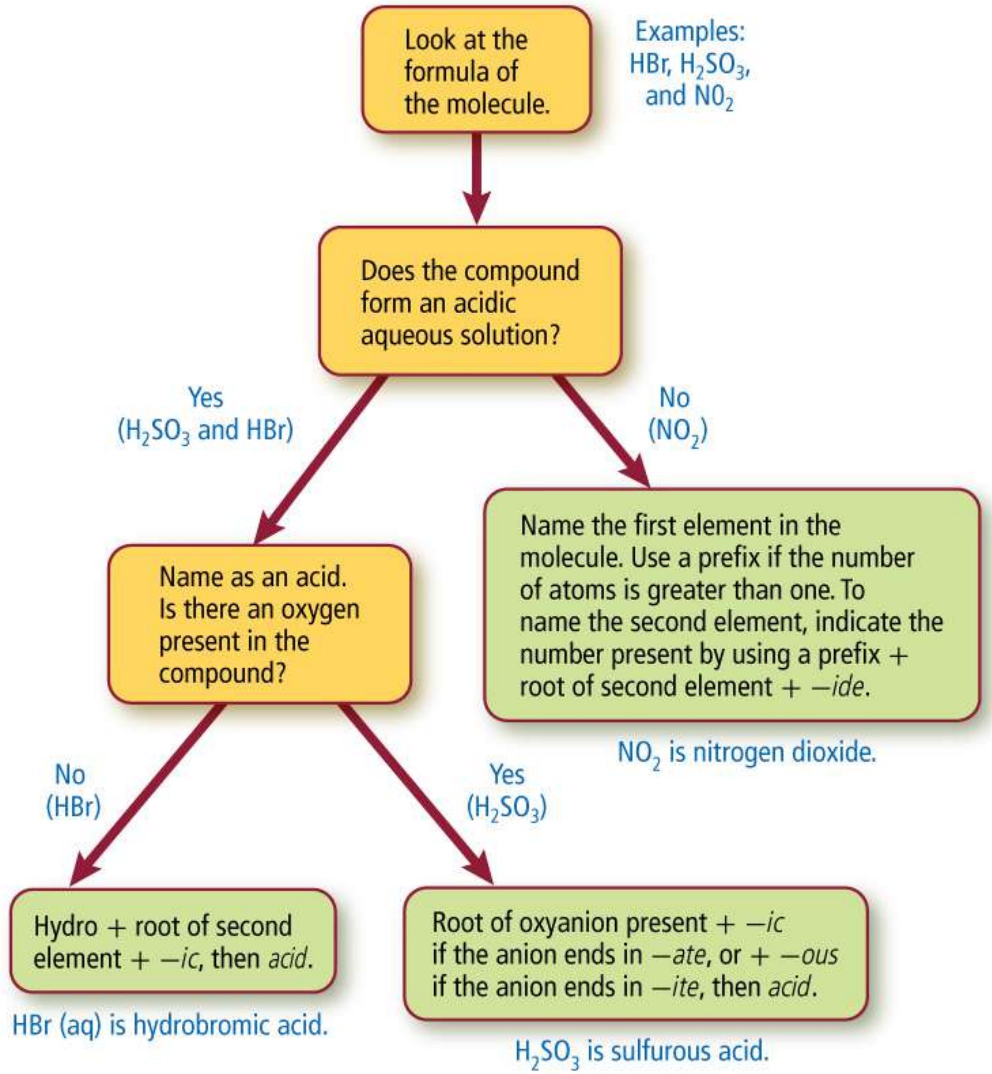
Naming Acids (cont.)

- The name of a molecular compound reveals its composition and is important in communicating the nature of the compound.

Naming Acids (cont.)



CheckPoint

Section 8.2 Assessment

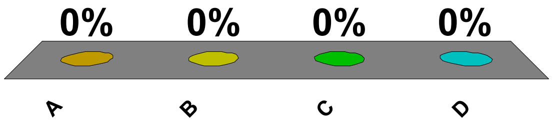
Give the binary molecular name for water (H_2O).

A. dihydrogen oxide

B. dihydroxide

C. hydrogen monoxide

D. dihydrogen monoxide



Section 8.2 Assessment

CheckPoint

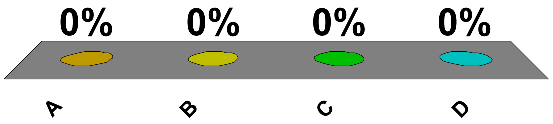
Give the name for the molecule $HClO_4$.

A. perchloric acid

B. chloric acid

C. chlorous acid

D. hydrochloric acid



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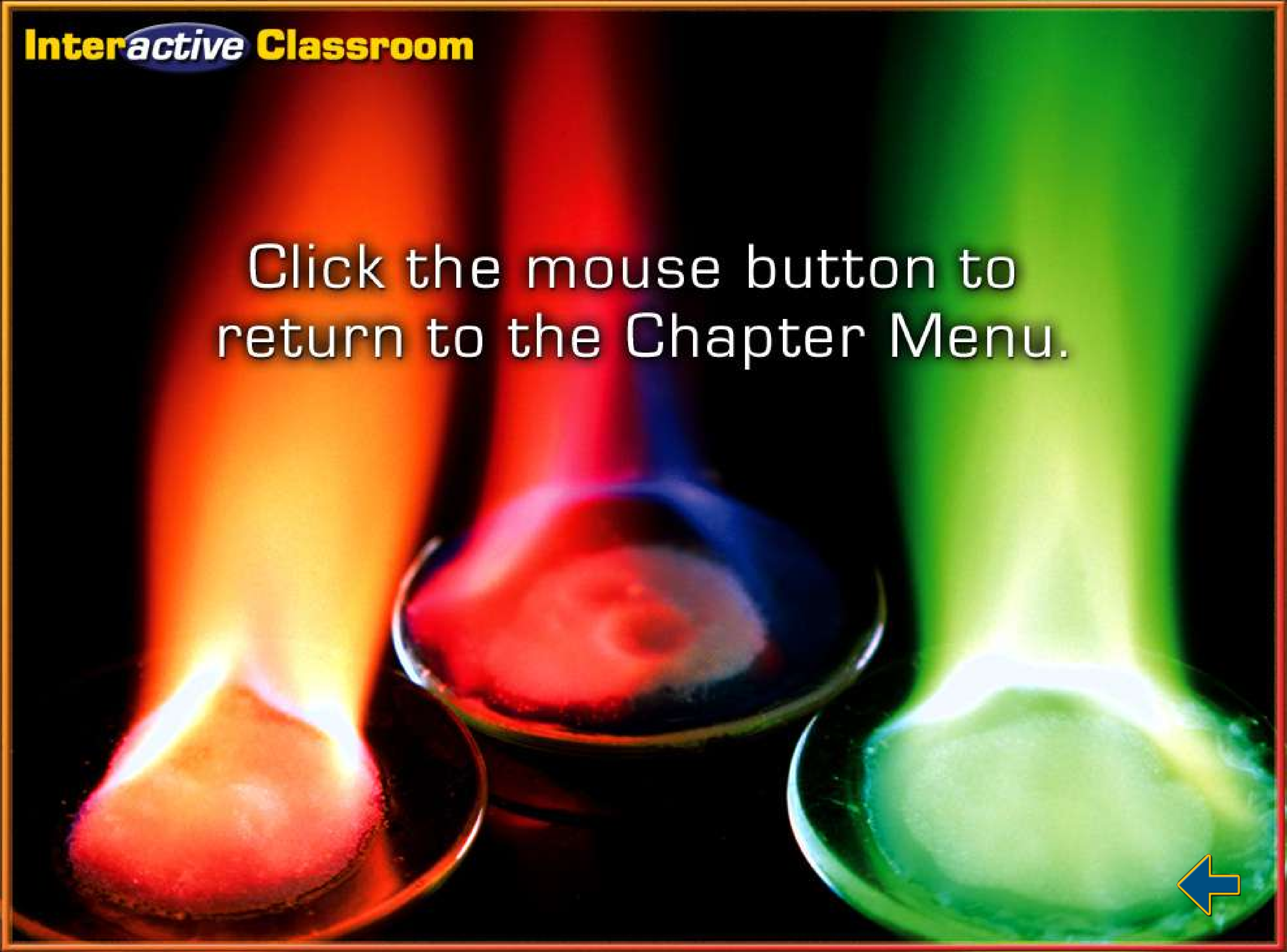


Section 8.3 Molecular Structures

Objectives

- **List** the basic steps used to draw Lewis structures.
- **Explain** why resonance occurs, and identify resonance structures.
- **Identify** three exceptions to the octet rule, and name molecules in which these exceptions occur.

Review Vocabulary

ionic bond: the electrostatic force that holds oppositely charged particles together in an ionic compound

Section 8.3 Molecular Structures (cont.)

New Vocabulary

structural formula

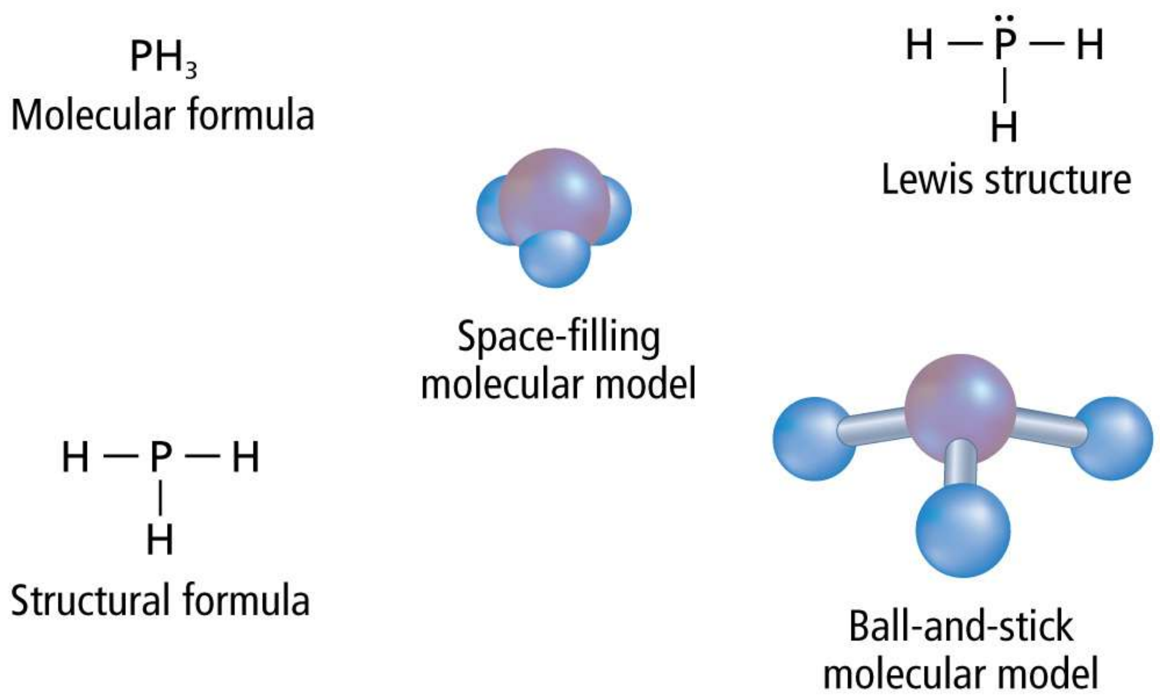
resonance

coordinate covalent bond

MAIN Idea **Structural formulas show the relative positions of atoms within a molecule.**

Structural Formulas

- A **structural formula** uses letter symbols and bonds to show relative positions of atoms.



Structural Formulas (cont.)

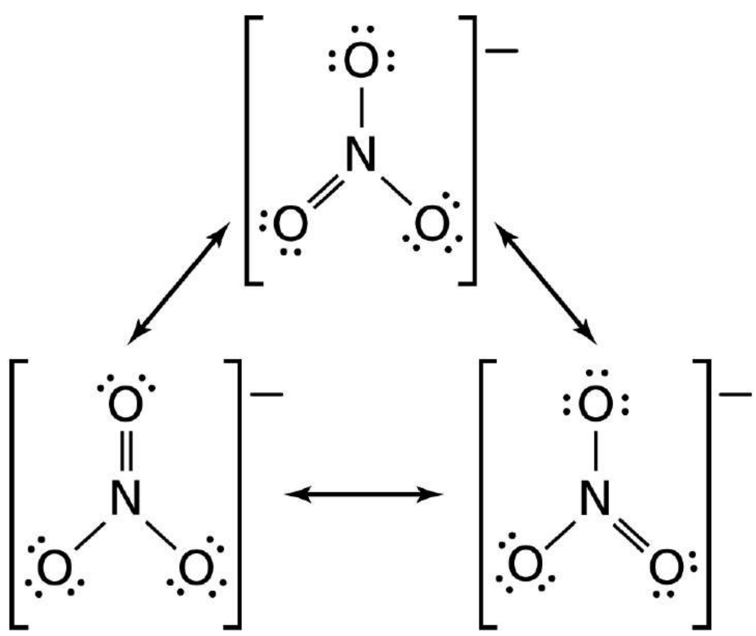
- Drawing Lewis Structures
  - Predict the location of certain atoms.
  - Determine the number of electrons available for bonding.
  - Determine the number of bonding pairs.
  - Place the bonding pairs.
  - Determine the number of bonding pairs remaining.
  - Determine whether the central atom satisfies the octet rule.

Structural Formulas (cont.)

- Atoms within a polyatomic ion are covalently bonded.

Resonance Structures

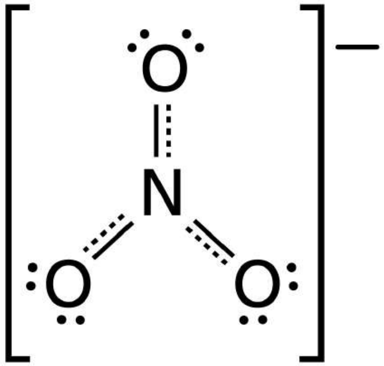
- **Resonance** is a condition that occurs when more than one valid Lewis structure can be written for a molecule or ion.



- This figure shows three correct ways to draw the structure for $(NO_3)^1$.

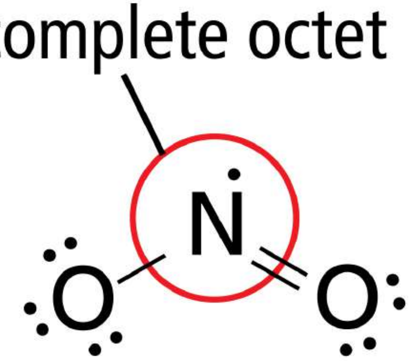
Resonance Structures (cont.)

- Two or more correct Lewis structures that represent a single ion or molecule are resonance structures.
- The molecule behaves as though it has only one structure.
- The bond lengths are identical to each other and intermediate between single and double covalent bonds.



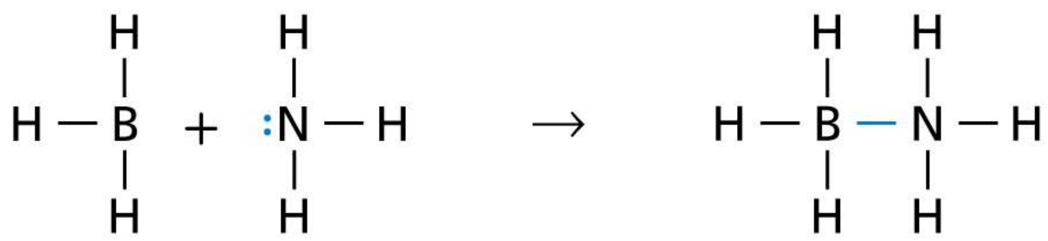
Exceptions to the Octet Rule

- Some molecules do not obey the octet rule.
- A small group of molecules might have an odd number of valence electrons.
- NO_2 has five valence electrons from nitrogen and 12 from oxygen and cannot form an exact number of electron pairs.



Exceptions to the Octet Rule (cont.)

- A few compounds form stable configurations with less than 8 electrons around the atom—a suboctet.
- A **coordinate covalent bond** forms when one atom donates both of the electrons to be shared with an atom or ion that needs two electrons.

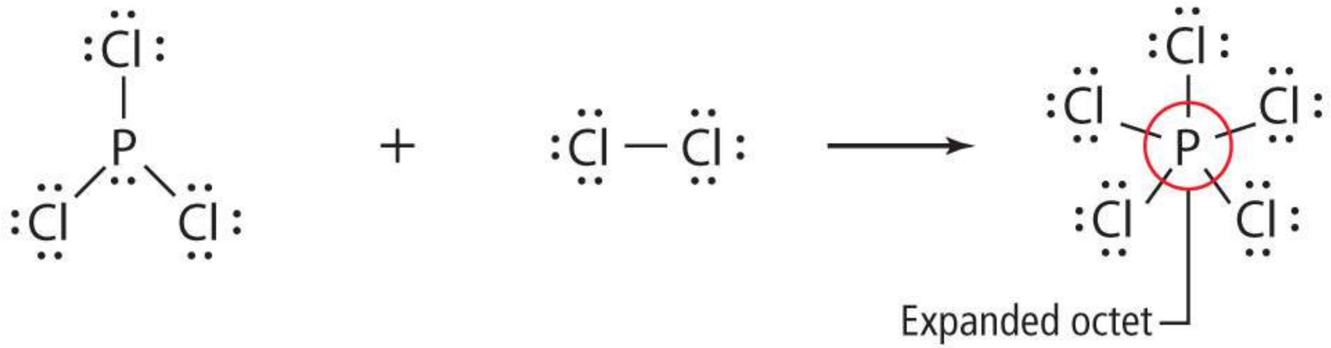


The boron atom has no electrons to share, whereas the nitrogen atom has two electrons to share.

The nitrogen atom shares both electrons to form the coordinate covalent bond.

Exceptions to the Octet Rule (cont.)

- A third group of compounds has central atoms with more than eight valence electrons, called an expanded octet.
- Elements in period 3 or higher have a d-orbital and can form more than four covalent bonds.



Section 8.3 Assessment

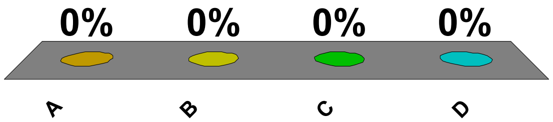
What is it called when one or more correct Lewis structures can be drawn for a molecule?

A. suboctet

B. expanded octet

C. expanded structure

D. resonance



Section 8.3 Assessment

CheckPoint

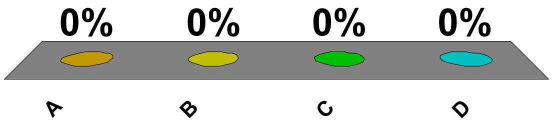
Where do atoms with expanded octets occur?

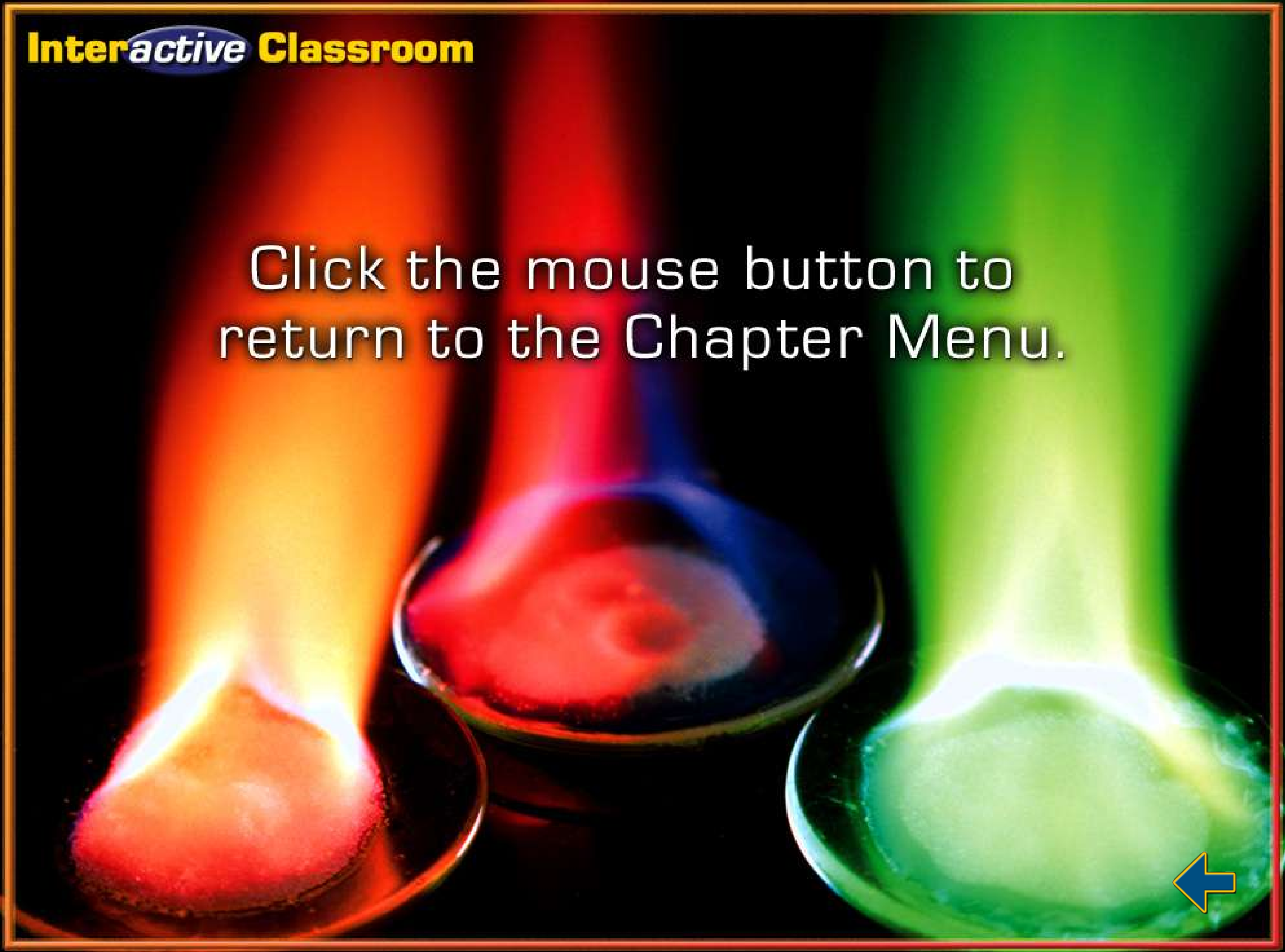
A. transition metals

B. noble gases

C. elements in period 3 or higher

D. elements in group 3 or higher

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Section 8.4 Molecular Shapes

Objectives

- **Summarize** the VSEPR bonding theory.
- **Predict** the shape of, and the bond angles in, a molecule.
- **Define** hybridization.

Review Vocabulary

atomic orbital: the region around an atom's nucleus that defines an electron's probable location

New Vocabulary

VSEPR model

hybridization

MAIN Idea **The VSEPR model is used to determine molecular shape.**

VSEPR Model

- The shape of a molecule determines many of its physical and chemical properties.
- Molecular geometry (shape) can be determined with the Valence Shell Electron Pair Repulsion model, or **VSEPR model** which minimizes the repulsion of shared and unshared atoms around the central atom.

VSEPR Model (cont.)

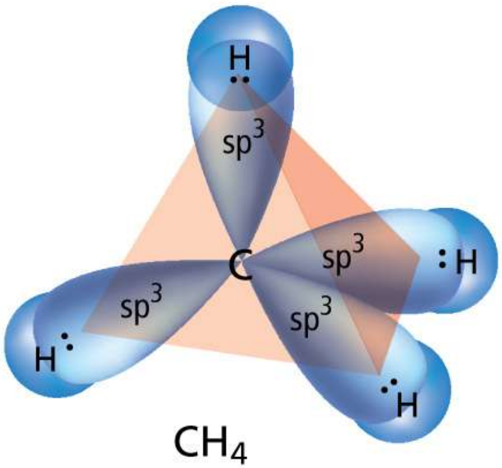
- Electron pairs repel each other and cause molecules to be in fixed positions relative to each other.
- Unshared electron pairs also determine the shape of a molecule.
- Electron pairs are located in a molecule as far apart as they can be.

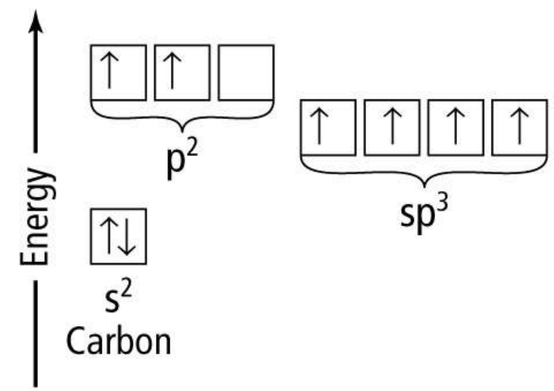
Hybridization

- **Hybridization** is a process in which atomic orbitals mix and form new, identical hybrid orbitals.
- Carbon often undergoes hybridization, which forms an sp^3 orbital formed from one s orbital and three p orbitals.
- Lone pairs also occupy hybrid orbitals.

Hybridization (cont.)

- Single, double, and triple bonds occupy only one hybrid orbital (CO_2 with two double bonds forms an sp hybrid orbital).





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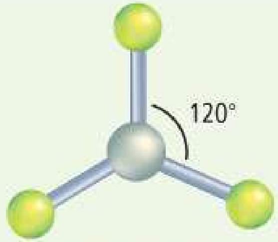
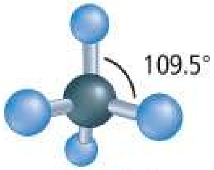
Hybridization (cont.)

Table 8.6 Molecular Shapes

Molecule	Total Pairs	Shared Pairs	Lone Pairs	Hybrid Orbitals	Molecular Shape*
$BeCl_2$	2	2	0	sp	 Linear
$AlCl_3$	3	3	0	sp^2	 Trigonal planar
CH_4	4	4	0	sp^3	 Tetrahedral

The $BeCl_2$ molecule contains only two pairs of electrons shared with the central Be atom. These bonding electrons have the maximum separation, a bond angle of 180°, and the molecular shape is linear.

The three bonding electron pairs in $AlCl_3$ have maximum separation in a trigonal planar shape with 120° bond angles.

When the central atom in a molecule has four pairs of bonding electrons, as CH_4 does, the shape is tetrahedral. The bond angles are 109.5°.

Concepts In Motion
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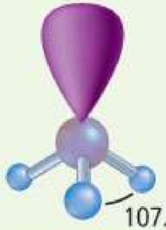
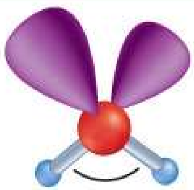
Hybridization (cont.)

Table 8.6 Molecular Shapes

Molecule	Total Pairs	Shared Pairs	Lone Pairs	Hybrid Orbitals	Molecular Shape*
PH_3	4	3	1	sp^3	 107.3° **Trigonal pyramidal**
H_2O	4	2	2	sp^3	 104.5° **Bent**

PH_3 has three single covalent bonds and one lone pair. The lone pair takes up a greater amount of space than the shared pairs. There is stronger repulsion between the lone pair and the bonding pairs than between two bonding pairs. The resulting geometry is trigonal pyramidal, with 107.3° bond angles.

Water has two covalent bonds and two lone pairs. Repulsion between the lone pairs causes the angle to be 104.5°, less than both tetrahedral and trigonal pyramid. As a result, water molecules have a bent shape.

Concepts In Motion

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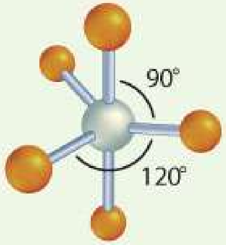
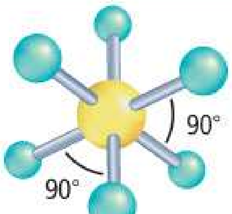
Hybridization (cont.)

Table 8.6 Molecular Shapes

Molecule	Total Pairs	Shared Pairs	Lone Pairs	Hybrid Orbitals	Molecular Shape*
$NbBr_5$	5	5	0	sp^3d	 Trigonal bipyramidal
SF_6	6	6	0	sp^3d^2	 Octahedral

The $NbBr_5$ molecule has five pairs of bonding electrons. The trigonal bipyramidal shape minimizes the repulsion of these shared electron pairs.

As with $NbBr_5$, SF_6 has no unshared electron pairs on the central atom. However, six shared pairs arranged about the central atom result in an octahedral shape.

Concepts In Motion
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Section 8.4 Assessment

CheckPoint

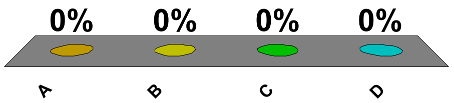
The two lone pairs of electrons on a water molecule do what to the bond angle between the hydrogen atoms and the oxygen atom?

A. They attract the hydrogen atoms and increase the angle greater than 109.5°.

B. They occupy more space and squeeze the hydrogen atoms closer together.

C. They do no affect the bond angle.

D. They create resonance structures with more than one correct angle.



Section 8.4 Assessment

CheckPoint

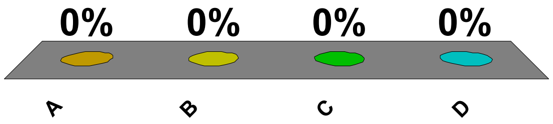
The sp^3 hybrid orbital in CH_4 has what shape?

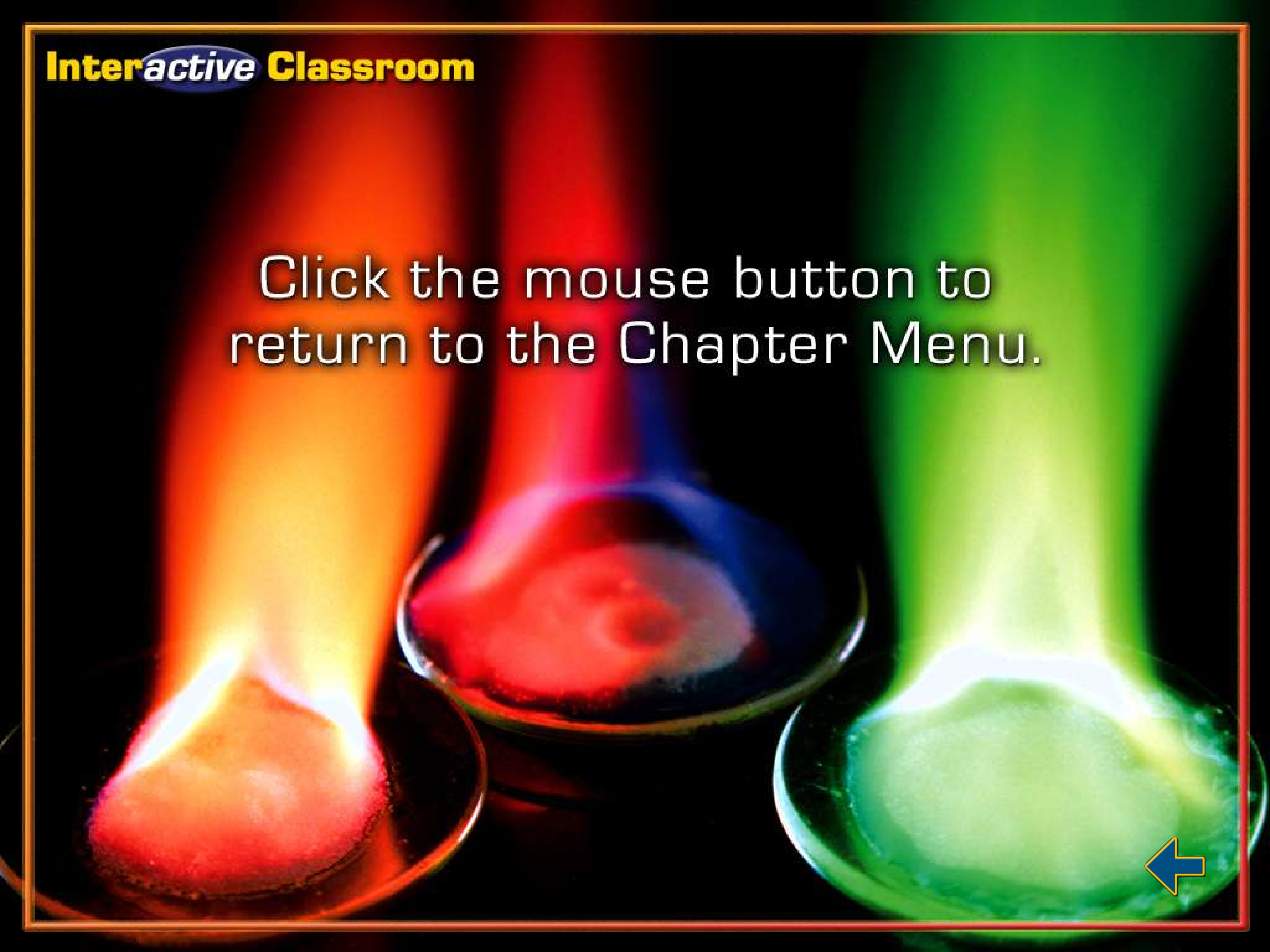
A. linear

B. trigonal planar

C. tetrahedral

D. octahedral

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Section 8.5 Electronegativity and Polarity

Objectives

- **Describe** how electronegativity is used to determine bond type.
- **Compare and contrast** polar and nonpolar covalent bonds and polar and nonpolar molecules.
- **Generalize** about the characteristics of covalently bonded compounds.

Review Vocabulary

electronegativity: the relative ability of an atom to attract electrons in a chemical bond

Section 8.5 Electronegativity and Polarity (cont.)

New Vocabulary

polar covalent bond

MAIN Idea

A chemical bond's character is related to each atom's attraction for the electrons in the bond.

Electron Affinity, Electronegativity, and Bond Character

- Electron affinity measures the tendency of an atom to accept an electron.

Electronegativity Values for Selected Elements

Metal
Metalloid
Nonmetal

1 H 2.20																
3 Li 0.98	4 Be 1.57											5 B 2.04	6 C 2.55	7 N 3.04	8 O 3.44	9 F 3.98
11 Na 0.93	12 Mg 1.31											13 Al 1.61	14 Si 1.90	15 P 2.19	16 S 2.58	17 Cl 3.16
19 K 0.82	20 Ca 1.00	21 Sc 1.36	22 Ti 1.54	23 V 1.63	24 Cr 1.66	25 Mn 1.55	26 Fe 1.83	27 Co 1.88	28 Ni 1.91	29 Cu 1.90	30 Zn 1.65	31 Ga 1.81	32 Ge 2.01	33 As 2.18	34 Se 2.55	35 Br 2.96
37 Rb 0.82	38 Sr 0.95	39 Y 1.22	40 Zr 1.33	41 Nb 1.6	42 Mo 2.16	43 Tc 2.10	44 Ru 2.2	45 Rh 2.28	46 Pd 2.20	47 Ag 1.93	48 Cd 1.69	49 In 1.78	50 Sn 1.96	51 Sb 2.05	52 Te 2.1	53 I 2.66
55 Cs 0.79	56 Ba 0.89	57 La 1.10	72 Hf 1.3	73 Ta 1.5	74 W 1.7	75 Re 1.9	76 Os 2.2	77 Ir 2.2	78 Pt 2.2	79 Au 2.4	80 Hg 1.9	81 Tl 1.8	82 Pb 1.8	83 Bi 1.9	84 Po 2.0	85 At 2.2
87 Fr 0.7	88 Ra 0.9	89 Ac 1.1														

- Noble gases are not listed because they generally do not form compounds.

Electron Affinity, Electronegativity, and Bond Character (cont.)

- This table lists the character and type of chemical bond that forms with differences in electronegativity.

Table 8.7 EN Difference and Bond Character

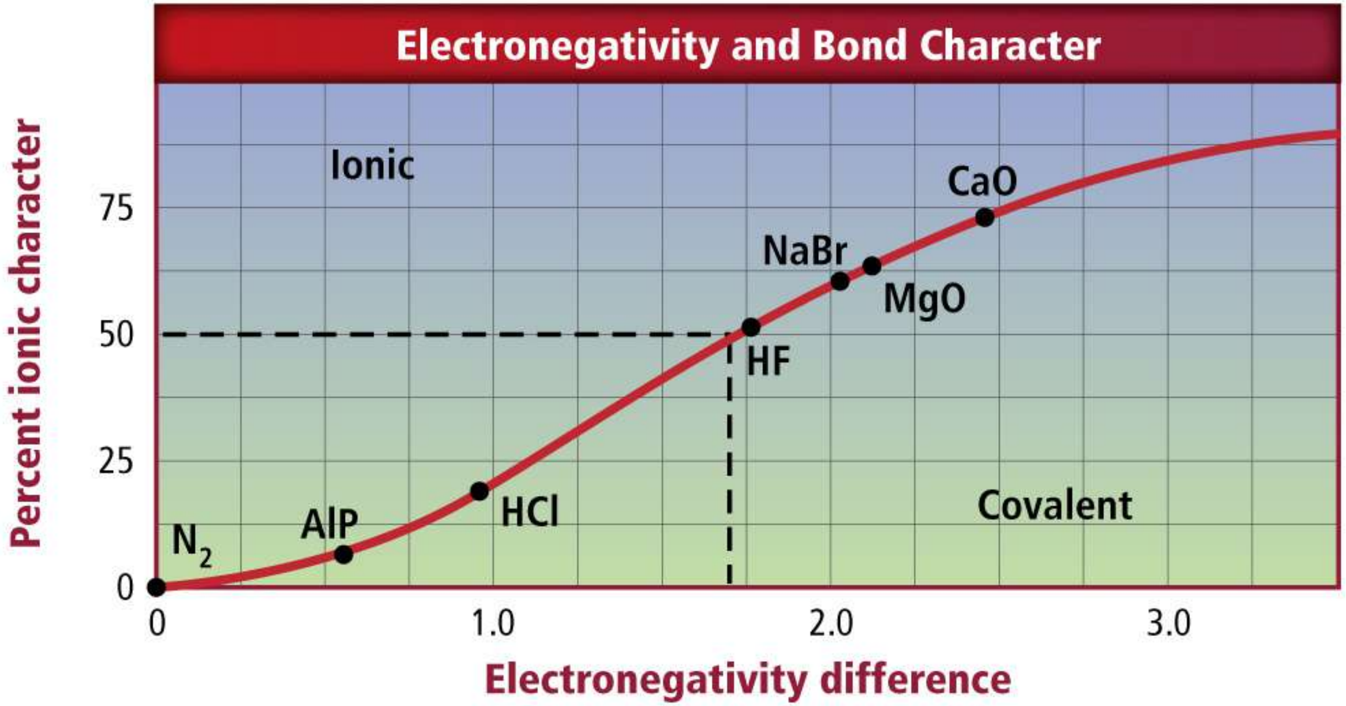
Electronegativity Difference	Bond Character
> 1.7	mostly ionic
0.4 – 1.7	polar covalent
< 0.4	mostly covalent
0	nonpolar covalent

Electron Affinity, Electronegativity, and Bond Character (cont.)

- Unequal sharing of electrons results in a **polar covalent bond**.
- Bonding is often not clearly ionic or covalent.

Electron Affinity, Electronegativity, and Bond Character (cont.)

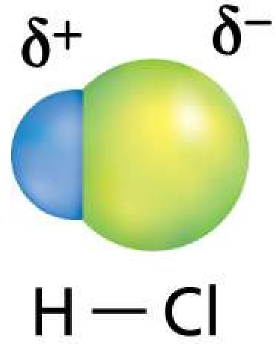
- This graph summarizes the range of chemical bonds between two atoms.



Polar Covalent Bonds

- Polar covalent bonds form when atoms pull on electrons in a molecule unequally.
- Electrons spend more time around one atom than another resulting in partial charges at the ends of the bond called a dipole.

$$\begin{array}{l} \text{Electronegativity Cl} = 3.16 \\ \text{Electronegativity H} = 2.20 \\ \hline \text{Difference} = 0.96 \end{array}$$



Concepts In Motion
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Polar Covalent Bonds (cont.)

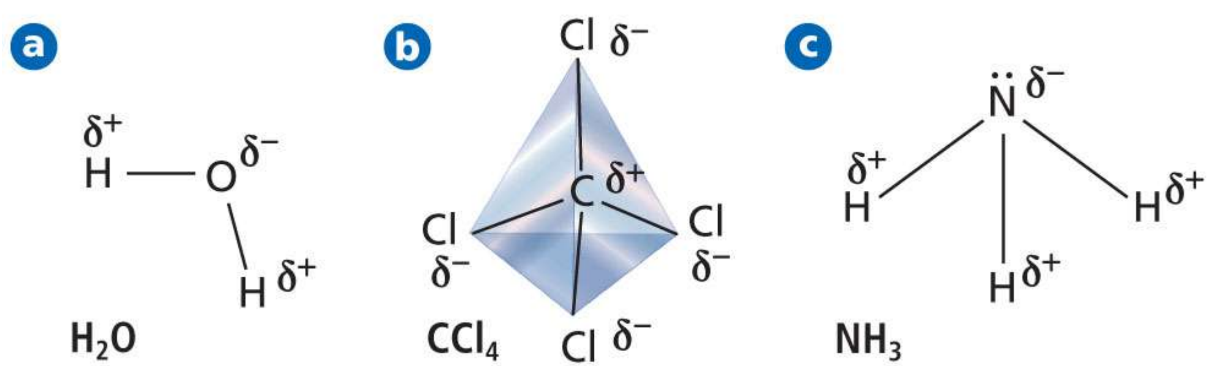
- Covalently bonded molecules are either polar or non-polar.
- Non-polar molecules are not attracted by an electric field.
- Polar molecules align with an electric field.

Polar Covalent Bonds (cont.)

- Compare water and CCl_4.
- Both bonds are polar, but only water is a polar molecule because of the shape of the molecule.

Polar Covalent Bonds (cont.)

- The electric charge on a CCl_4 molecule measured at any distance from the center of the molecule is identical to the charge measured at the same distance on the opposite side.



The bent shape of a water molecule makes it polar.

The symmetry of a CCl_4 molecule results in an equal distribution of charge, and the molecule is nonpolar.

The asymmetric shape of an ammonia molecule results in an unequal charge distribution and the molecule is polar.

Polar Covalent Bonds (cont.)

- Solubility is the property of a substance’s ability to dissolve in another substance.
- Polar molecules and ionic substances are usually soluble in polar substances.
- Non-polar molecules dissolve only in non-polar substances.

Properties of Covalent Compounds

- Covalent bonds between atoms are strong, but attraction forces between molecules are weak.
- The weak attraction forces are known as van der Waals forces.
- The forces vary in strength but are weaker than the bonds in a molecule or ions in an ionic compound.

Properties of Covalent Compounds (cont.)

- Non-polar molecules exhibit a weak dispersion force, or induced dipole.
- The force between two oppositely charged ends of two polar molecules is a dipole-dipole force.
- A hydrogen bond is an especially strong dipole-dipole force between a hydrogen end of one dipole and a fluorine, oxygen, or nitrogen atom on another dipole.

Properties of Covalent Compounds (cont.)

- Many physical properties are due to intermolecular forces.
- Weak forces result in the relatively low melting and boiling points of molecular substances.
- Many covalent molecules are relatively soft solids.
- Molecules can align in a crystal lattice, similar to ionic solids but with less attraction between particles.

Properties of Covalent Compounds (cont.)

- Solids composed of only atoms interconnected by a network of covalent bonds are called covalent network solids.
- Quartz and diamonds are two common examples of network solids.

Section 8.5 Assessment

CheckPoint

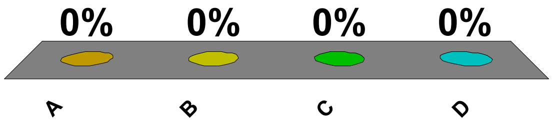
The force between water molecules is what kind of intermolecular force?

A. induced dipole

B. hydrogen bond

C. sigma bond

D. partial dipole



CheckPoint

Section 8.5 Assessment

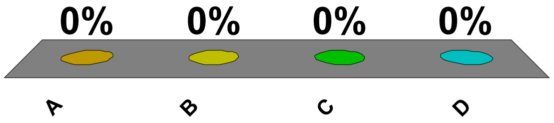
What kind of bond occurs within a molecule with unequal sharing of electron pairs?

A. ionic bond

B. sigma bond

C. non-polar covalent bond

D. polar covalent bond



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Study Guide

Section 8.1 The Covalent Bond

Key Concepts

- Covalent bonds form when atoms share one or more pairs of electrons.
- Sharing one pair, two pairs, and three pairs of electrons forms single, double, and triple covalent bonds, respectively.
- Orbitals overlap directly in sigma bonds. Parallel orbitals overlap in pi bonds. A single covalent bond is a sigma bond but multiple covalent bonds are made of both sigma and pi bonds.
- Bond length is measured nucleus-to-nucleus. Bond dissociation energy is needed to break a covalent bond.

Study Guide

Section 8.2 Naming Molecules

Key Concepts

- Names of covalent molecular compounds include prefixes for the number of each atom present. The final letter of the prefix is dropped if the element name begins with a vowel.
- Molecules that produce H^+ in solution are acids. Binary acids contain hydrogen and one other element. Oxyacids contain hydrogen and an oxyanion.

Study Guide

Section 8.3 Molecular Structures

Key Concepts

- Different models can be used to represent molecules.
- Resonance occurs when more than one valid Lewis structure exists for the same molecule.
- Exceptions to the octet rule occur in some molecules.

Study Guide

Section 8.4 Molecular Shapes

Key Concepts

- VSEPR model theory states that electron pairs repel each other and determine both the shape of and bond angles in a molecule.
- Hybridization explains the observed shapes of molecules by the presence of equivalent hybrid orbitals.

Study Guide

Section 8.5 Electronegativity and Polarity

Key Concepts

- The electronegativity difference determines the character of a bond between atoms.
- Polar bonds occur when electrons are not shared equally forming a dipole.
- The spatial arrangement of polar bonds in a molecule determines the overall polarity of a molecule.
- Molecules attract each other by weak intermolecular forces. In a covalent network solid, each atom is covalently bonded to many other atoms.

Chapter Assessment

CheckPoint

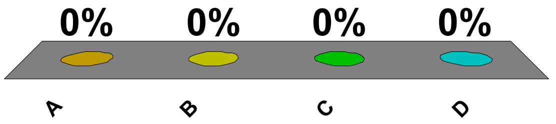
What type of bond results from two atoms sharing electrons?

A. hydrogen bond

B. covalent bond

C. ionic bond

D. dipole bond



Chapter Assessment

CheckPoint

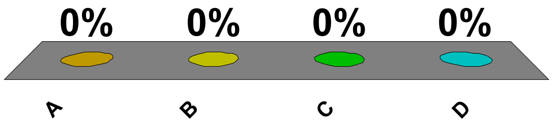
Give the correct name for the molecule HSO_4 in water solution.

A. hydrosulfuric acid

B. sulfuric acid

C. sulfurous acid

D. hydrogen sulfate



Chapter Assessment

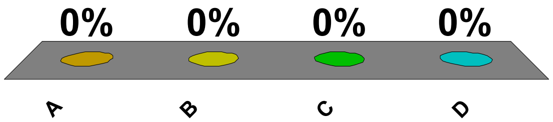
What molecule is an example of the expanded octet rule?

A. H_2O

B. BF_3

C. BeH_2

D. PCl_5



Chapter Assessment

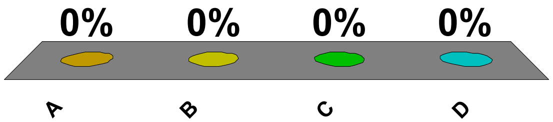
What is the molecular shape of a compound with the hybrid sp orbital?

A. linear

B. trigonal planar

C. tetrahedral

D. spherical



Chapter Assessment

CheckPoint

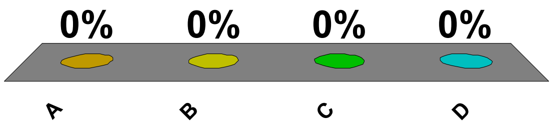
Which of the following is a polar molecule?

A. CCl_4

B. H_2

C. CH_4

D. NH_3



Standardized Test Practice

CheckPoint

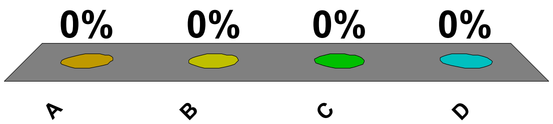
What is the molecular name for hydrazine (N_2H_4)?

A. nitrogen tetrahydride

B. dinitrogen tetrahydride

C. dinitrogen hydride

D. dinitrogen tetrachloride



Standardized Test Practice

CheckPoint

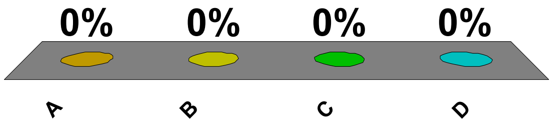
In general, electronegativity increases as:

A. you move up a group

B. you move down a group

C. you move from right to left across a period

D. none of the above



Standardized Test Practice

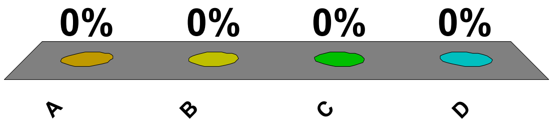
Which technique would you use to separate mixtures with different boiling points?

A. filtration

B. chromatography

C. distillation

D. sublimation



Standardized Test Practice

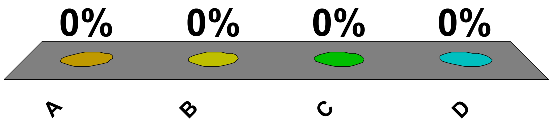
Which of the following contains an ionic bond?

A. LiBr

B. H_2O

C. F_2

D. CO_2



Standardized Test Practice

CheckPoint

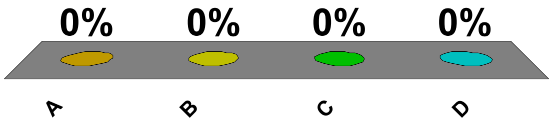
What are van der Waals forces?

A. forces between two ions

B. forces between two electrons

C. forces within a molecule

D. forces between two molecules



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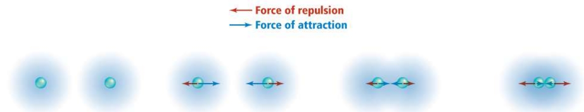
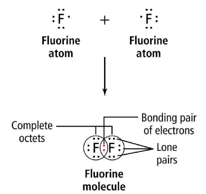
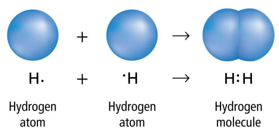
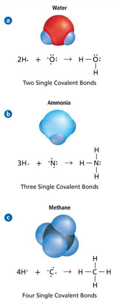
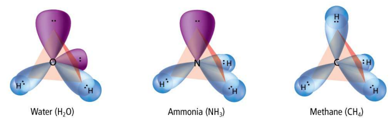
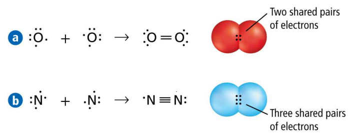












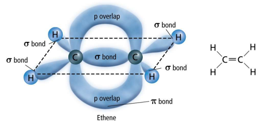


Table 8.1 Covalent Bond Type and Bond Length

Molecule	Bond Type	Bond Length
F_2	single covalent	1.43×10^{-10} m
O_2	double covalent	1.21×10^{-10} m
N_2	triple covalent	1.10×10^{-10} m

Table 8.2 Bond-Dissociation Energy

Molecule	Bond-Dissociation Energy
F_2	159 kJ/mol
O_2	498 kJ/mol
N_2	945 kJ/mol

Table 8.3 Prefixes in Covalent Compounds

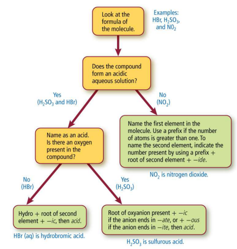
Number of Atoms	Prefix	Number of Atoms	Prefix
1	mono-	6	hexa-
2	di-	7	hepta-
3	tri-	8	octa-
4	tetra-	9	nona-
5	penta-	10	deca-

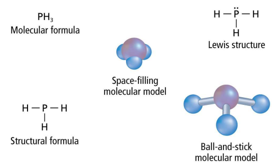
Table 8.4 Naming Oxyacids

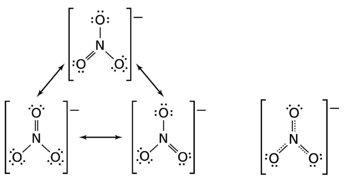
Compound	Oxyanion	Acid Suffix	Acid Name
$HClO_3$	chlorate	-ic	chloric acid
$HClO_2$	chlorite	-ous	chlorous acid
HNO_3	nitrate	-ic	nitric acid
HNO_2	nitrite	-ous	nitrous acid

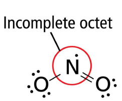
Table 8.5 Formulas and Names of Some Covalent Compounds

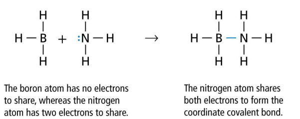
Formula	Common Name	Molecular Compound Name
H_2O	water	dihydrogen monoxide
NH_3	ammonia	nitrogen trihydride
N_2H_4	hydrazine	dinitrogen tetrahydride
HCl	muriatic acid	hydrochloric acid
$C_9H_8O_4$	aspirin	2-(acetyloxy)benzoic acid

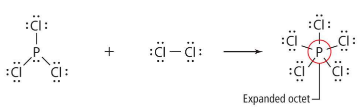


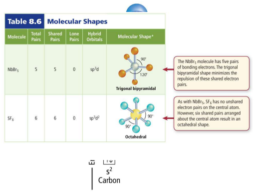


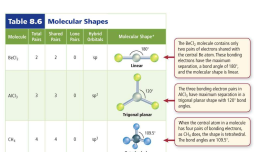


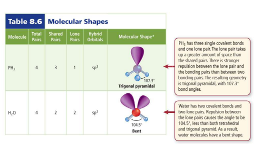












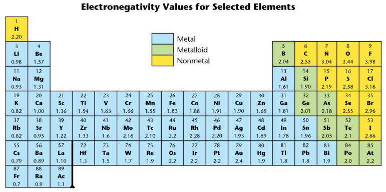
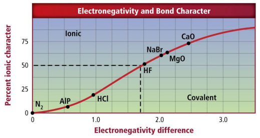
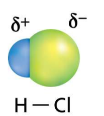


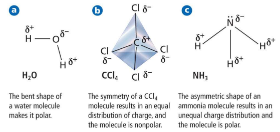
Table 8.7 EN Difference and Bond Character

Electronegativity Difference	Bond Character
> 1.7	mostly ionic
0.4 – 1.7	polar covalent
< 0.4	mostly covalent
0	nonpolar covalent



$$\text{Electronegativity Cl} = 3.16$$
$$\text{Electronegativity H} = 2.20$$
$$\text{Difference} = 0.96$$





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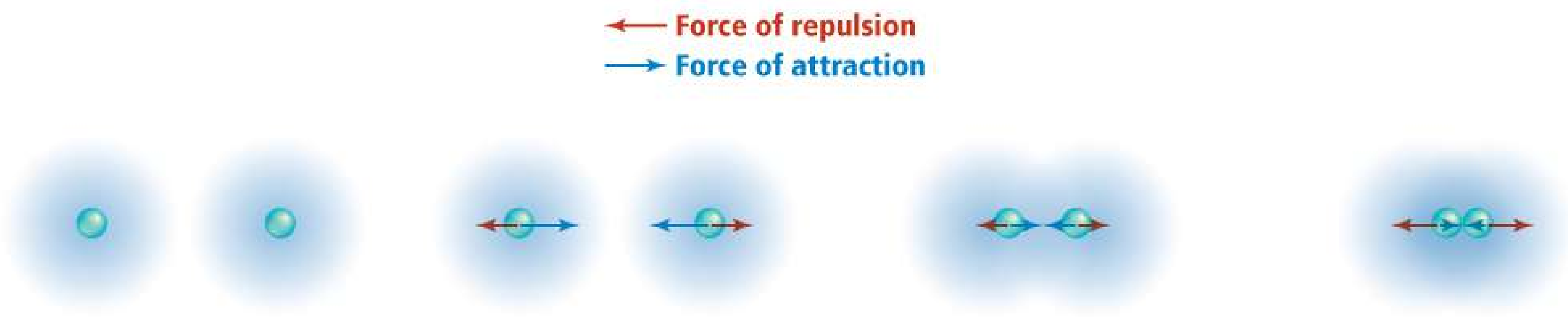

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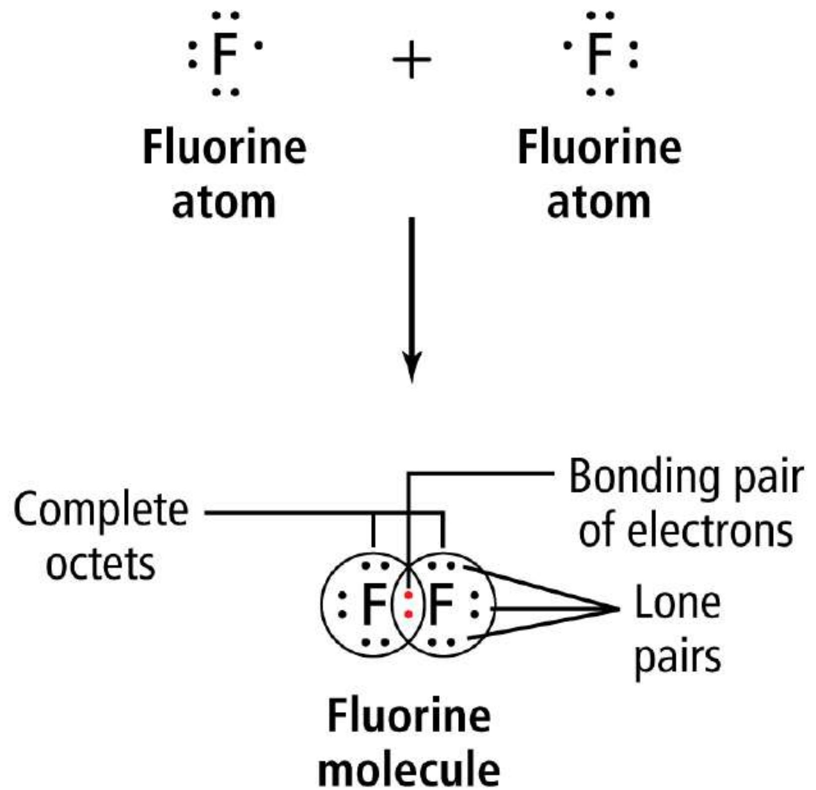
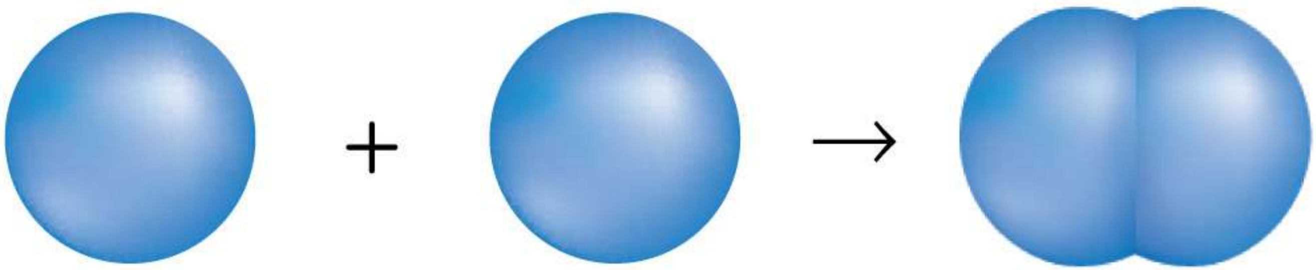

F
+
F
Fluorine atom
Fluorine atom
Complete octets
Bonding pair of electrons
F
F
Lone pairs
Fluorine molecule

Image Bank



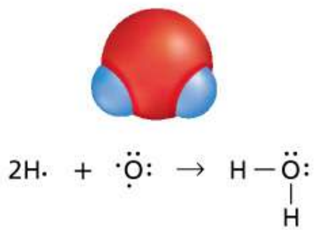
$H\cdot + \cdot H \rightarrow H:H$

Hydrogen atom + Hydrogen atom → Hydrogen molecule

Image Bank

Water

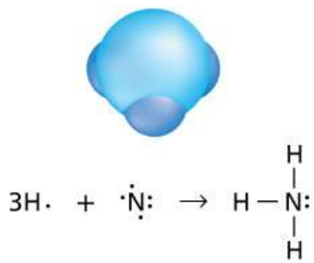
a



Two Single Covalent Bonds

Ammonia

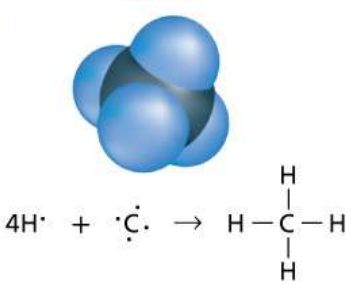
b



Three Single Covalent Bonds

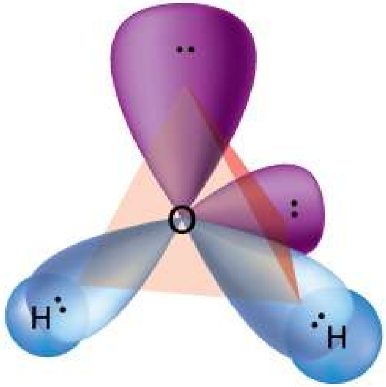
Methane

c

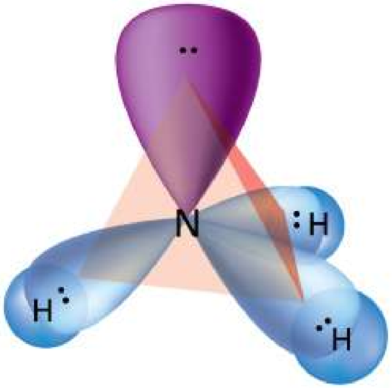


Four Single Covalent Bonds

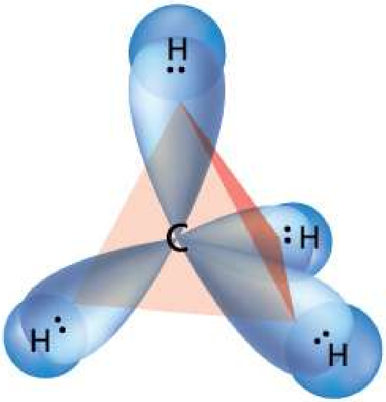
Image Bank



Water (H_2O)



Ammonia (NH_3)



Methane (CH_4)

Image Bank

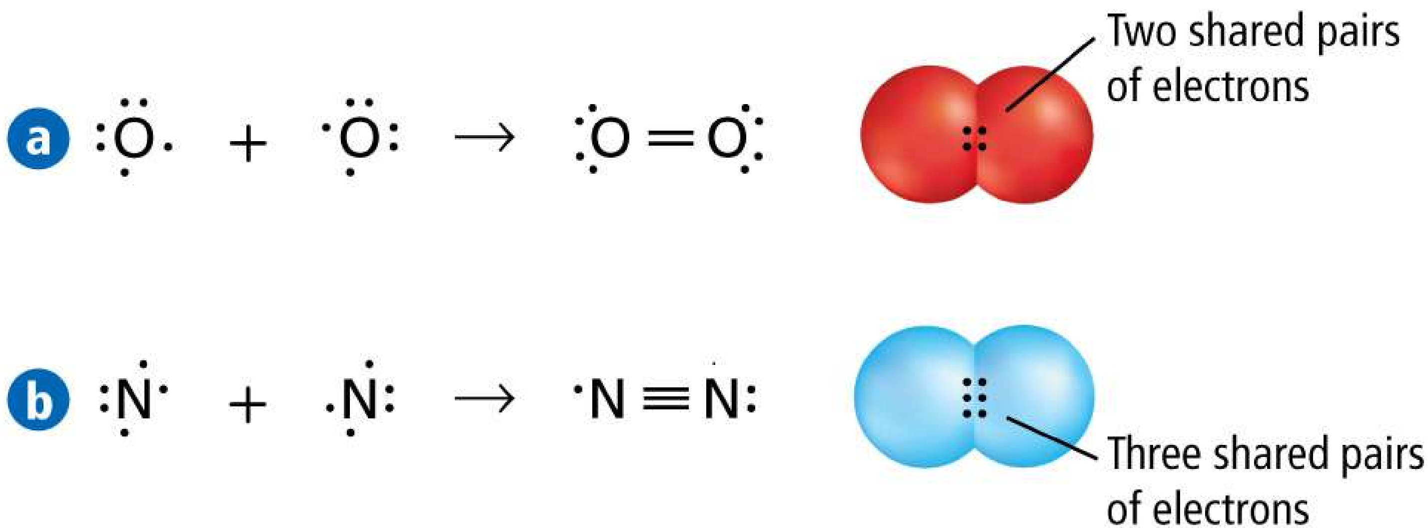
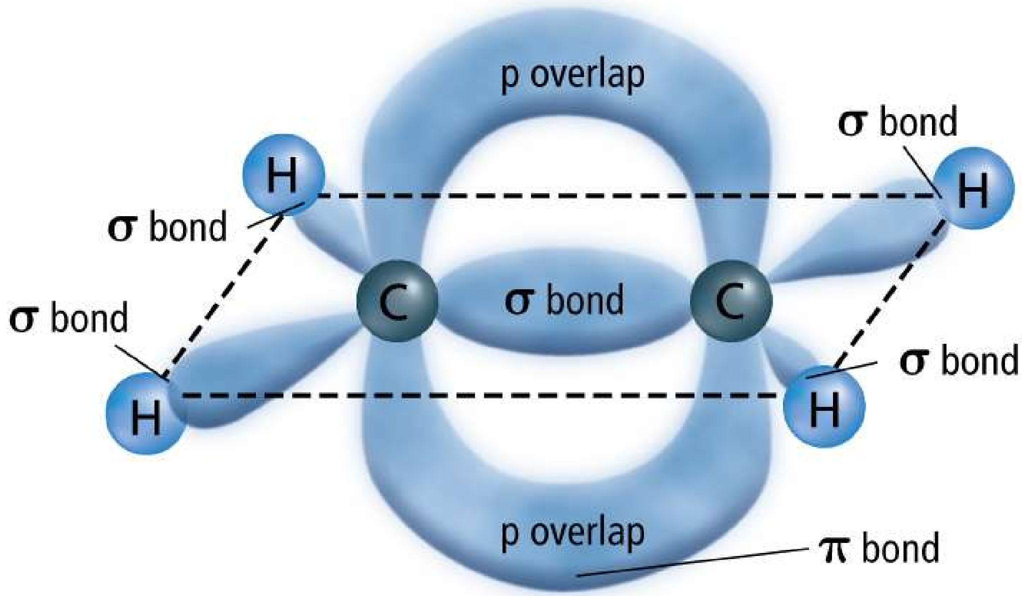

a
b
Two shared pairs of electrons
Three shared pairs of electrons

Image Bank



Ethene

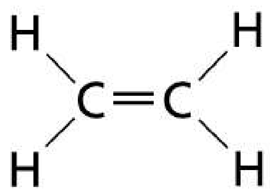


Image Bank

Table 8.1 Covalent Bond Type and Bond Length		
Molecule	**Bond Type**	**Bond Length**
F_2	single covalent	1.43×10^{-10} m
O_2	double covalent	1.21×10^{-10} m
N_2	triple covalent	1.10×10^{-10} m

Image Bank

Table 8.2	Bond-Dissociation Energy
Molecule	**Bond-Dissociation Energy**
F_2	159 kJ/mol
O_2	498 kJ/mol
N_2	945 kJ/mol

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Table 8.3 Prefixes in Covalent Compounds

Number of Atoms	Prefix	Number of Atoms	Prefix
1	mono-	6	hexa-
2	di-	7	hepta-
3	tri-	8	octa-
4	tetra-	9	nona-
5	penta-	10	deca-

Image Bank

Table 8.4 Naming Oxyacids

Compound	Oxyanion	Acid Suffix	Acid Name
$HClO_3$	chlorate	-ic	chloric acid
$HClO_2$	chlorite	-ous	chlorous acid
HNO_3	nitrate	-ic	nitric acid
HNO_2	nitrite	-ous	nitrous acid

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Table 8.5	Formulas and Names of Some Covalent Compounds	
Formula	Common Name	Molecular Compound Name
H_2O	water	dihydrogen monoxide
NH_3	ammonia	nitrogen trihydride
N_2H_4	hydrazine	dinitrogen tetrahydride
HCl	muriatic acid	hydrochloric acid
$C_9H_8O_4$	aspirin	2-(acetyloxy)benzoic acid

Image Bank

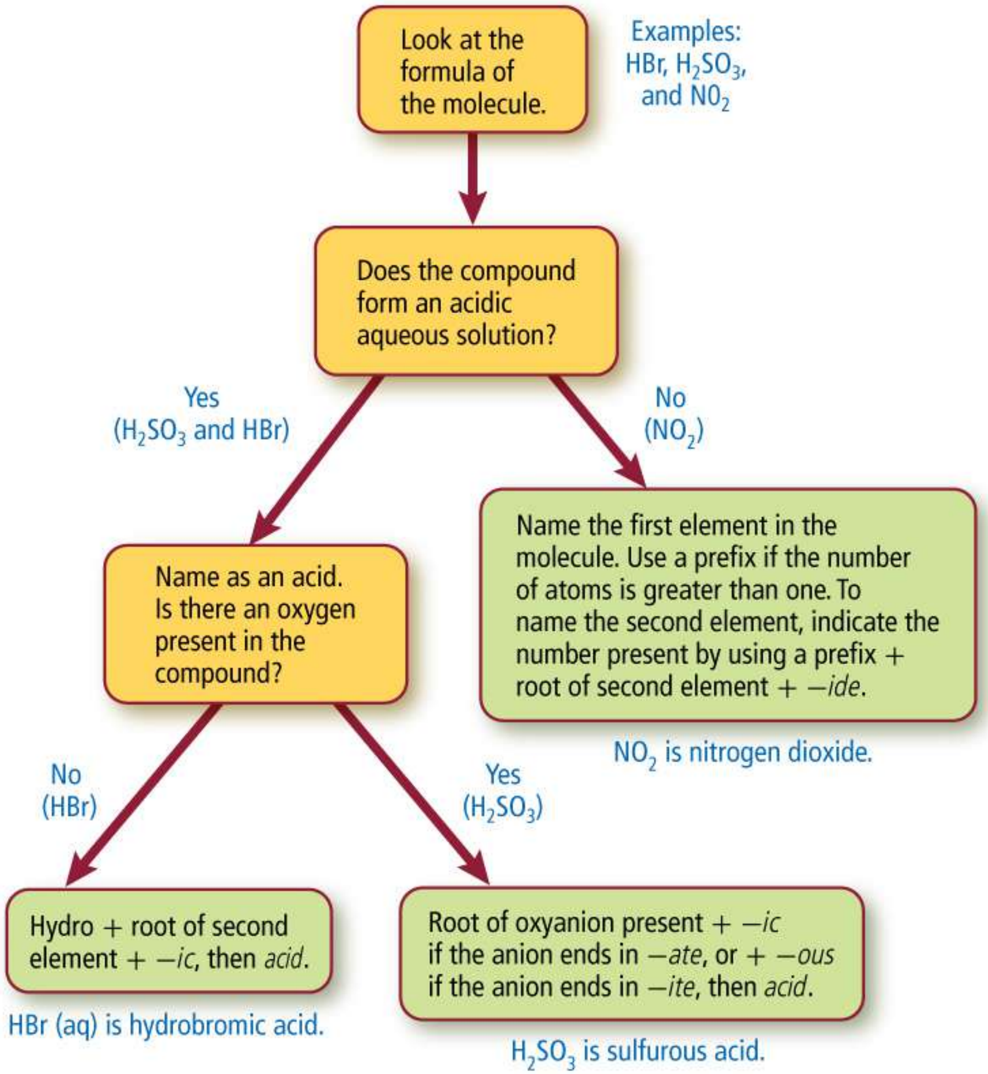

Look at the formula of the molecule.
Examples: HBr, H_2SO_3, and NO_2
Does the compound form an acidic aqueous solution?
Yes (H_2SO_3 and HBr)
No (NO_2)
Name as an acid. Is there an oxygen present in the compound?
Name the first element in the molecule. Use a prefix if the number of atoms is greater than one. To name the second element, indicate the number present by using a prefix + root of second element + –*ide*.
NO_2 is nitrogen dioxide.
No (HBr)
Yes (H_2SO_3)
Hydro + root of second element + –*ic*, then *acid*.
HBr (aq) is hydrobromic acid.
Root of oxyanion present + –*ic* if the anion ends in –*ate*, or + –*ous* if the anion ends in –*ite*, then *acid*.
H_2SO_3 is sulfurous acid.

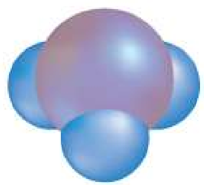
Image Bank

PH_3

Molecular formula

H — P̈ — H
 |
 H

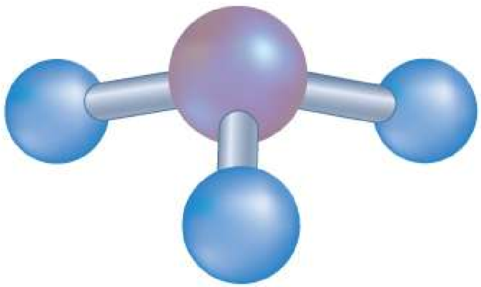
Lewis structure



Space-filling molecular model

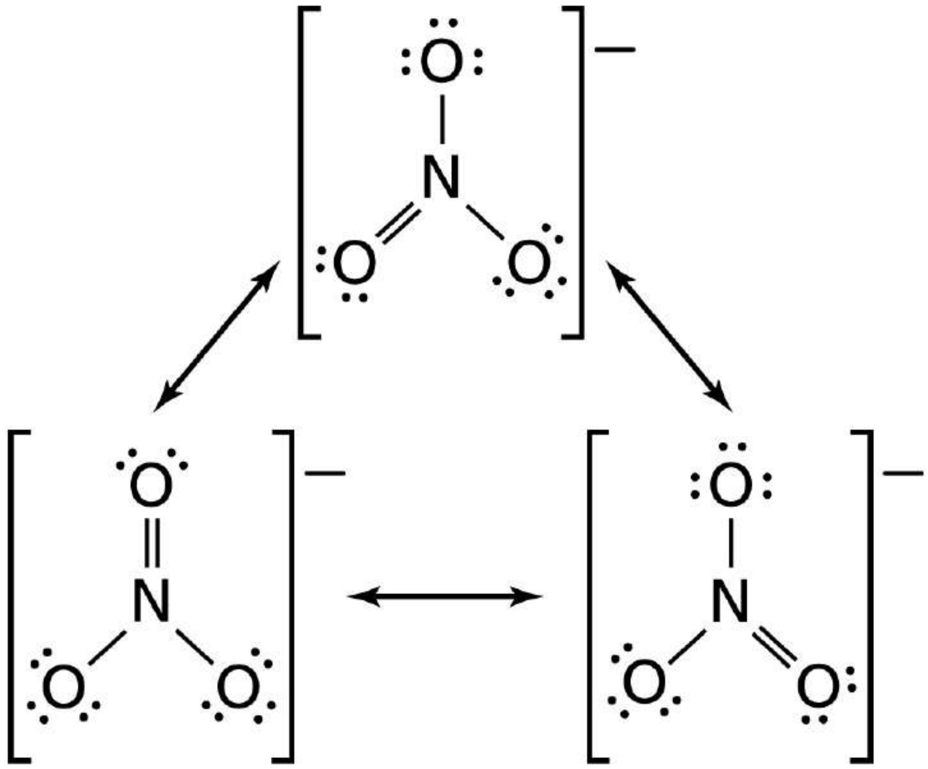
H — P — H
 |
 H

Structural formula



Ball-and-stick molecular model

Image Bank



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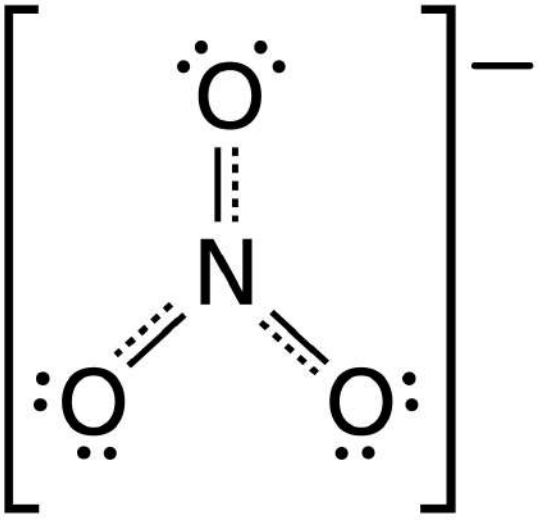

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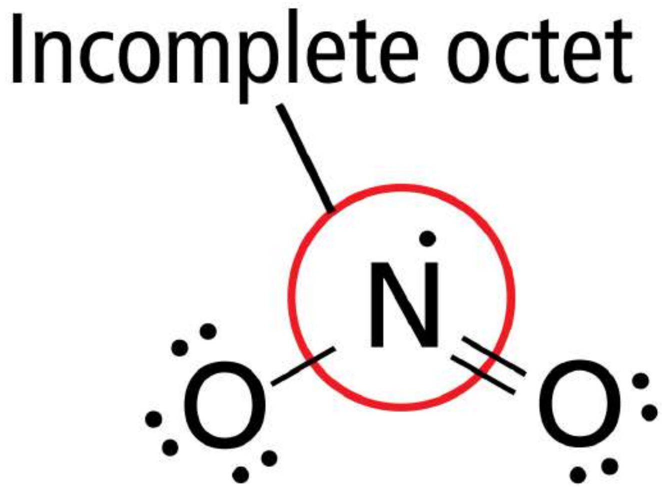

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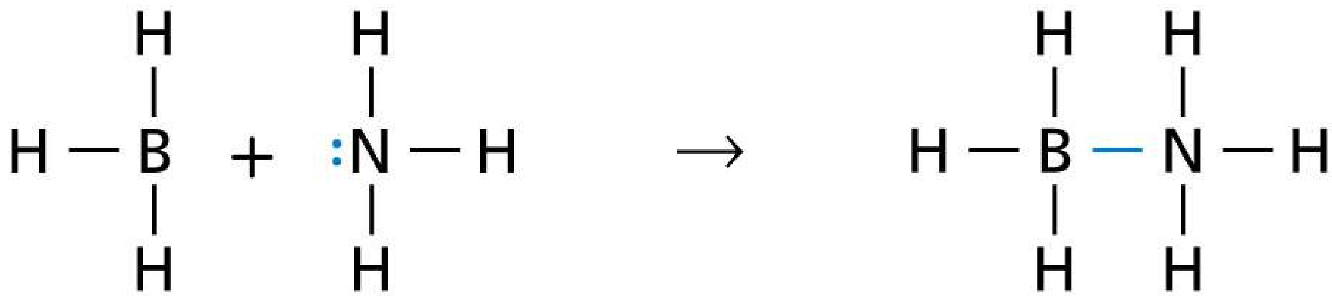
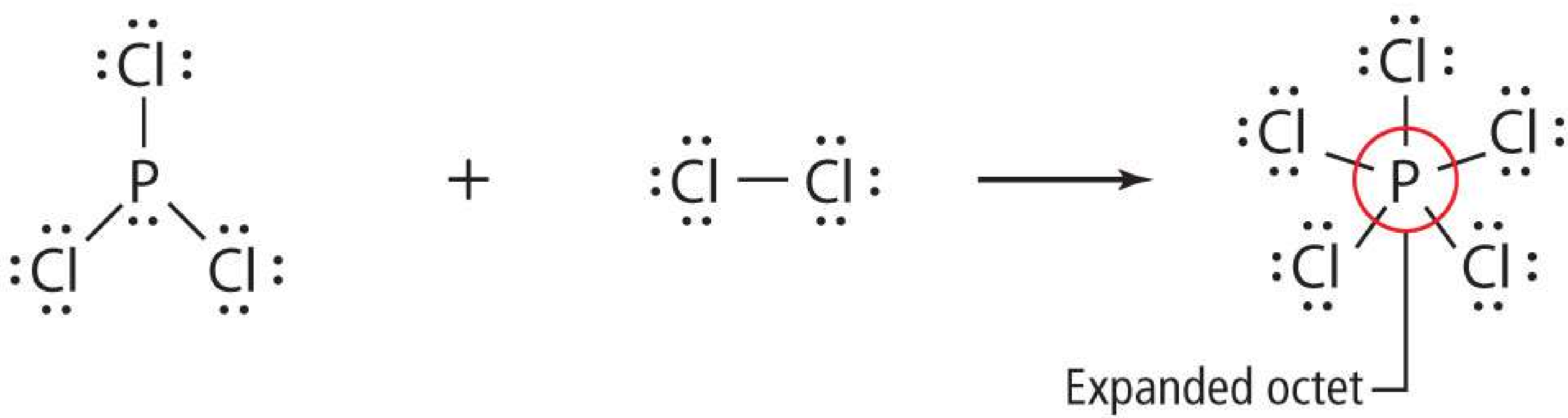


The boron atom has no electrons to share, whereas the nitrogen atom has two electrons to share.

The nitrogen atom shares both electrons to form the coordinate covalent bond.

Image Bank



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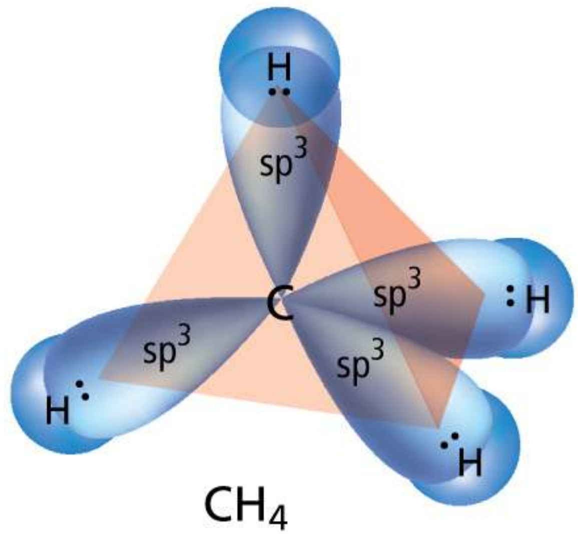

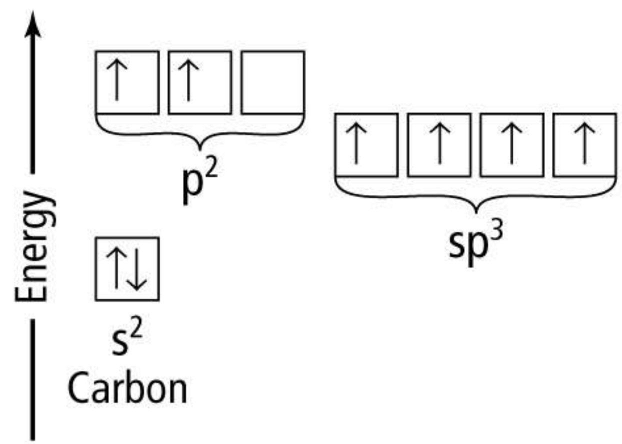

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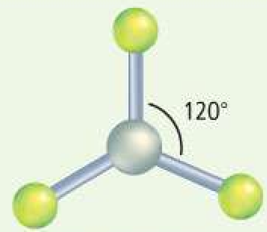
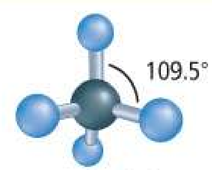
Table 8.6 Molecular Shapes

Molecule	Total Pairs	Shared Pairs	Lone Pairs	Hybrid Orbitals	Molecular Shape*
$BeCl_2$	2	2	0	sp	 Linear
$AlCl_3$	3	3	0	sp^2	 Trigonal planar
CH_4	4	4	0	sp^3	 Tetrahedral

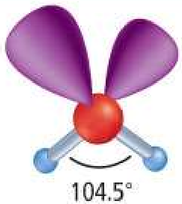
The $BeCl_2$ molecule contains only two pairs of electrons shared with the central Be atom. These bonding electrons have the maximum separation, a bond angle of 180°, and the molecular shape is linear.

The three bonding electron pairs in $AlCl_3$ have maximum separation in a trigonal planar shape with 120° bond angles.

When the central atom in a molecule has four pairs of bonding electrons, as CH_4 does, the shape is tetrahedral. The bond angles are 109.5°.

Image Bank

Table 8.6 Molecular Shapes

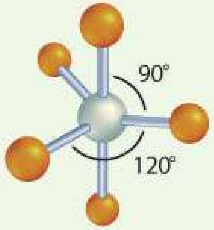
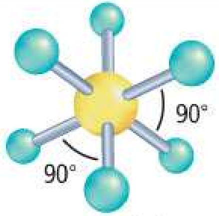
Molecule	Total Pairs	Shared Pairs	Lone Pairs	Hybrid Orbitals	Molecular Shape*
PH_3	4	3	1	sp^3	 Trigonal pyramidal
H_2O	4	2	2	sp^3	 Bent

PH_3 has three single covalent bonds and one lone pair. The lone pair takes up a greater amount of space than the shared pairs. There is stronger repulsion between the lone pair and the bonding pairs than between two bonding pairs. The resulting geometry is trigonal pyramidal, with 107.3° bond angles.

Water has two covalent bonds and two lone pairs. Repulsion between the lone pairs causes the angle to be 104.5°, less than both tetrahedral and trigonal pyramid. As a result, water molecules have a bent shape.

Image Bank

Table 8.6 Molecular Shapes

Molecule	Total Pairs	Shared Pairs	Lone Pairs	Hybrid Orbitals	Molecular Shape*
$NbBr_5$	5	5	0	sp^3d	 **Trigonal bipyramidal**
SF_6	6	6	0	sp^3d^2	 **Octahedral**

The $NbBr_5$ molecule has five pairs of bonding electrons. The trigonal bipyramidal shape minimizes the repulsion of these shared electron pairs.

As with $NbBr_5$, SF_6 has no unshared electron pairs on the central atom. However, six shared pairs arranged about the central atom result in an octahedral shape.

Image Bank

Electronegativity Values for Selected Elements

- Metal
- Metalloid
- Nonmetal

1 H 2.20																
3 Li 0.98	4 Be 1.57											5 B 2.04	6 C 2.55	7 N 3.04	8 O 3.44	9 F 3.98
11 Na 0.93	12 Mg 1.31											13 Al 1.61	14 Si 1.90	15 P 2.19	16 S 2.58	17 Cl 3.16
19 K 0.82	20 Ca 1.00	21 Sc 1.36	22 Ti 1.54	23 V 1.63	24 Cr 1.66	25 Mn 1.55	26 Fe 1.83	27 Co 1.88	28 Ni 1.91	29 Cu 1.90	30 Zn 1.65	31 Ga 1.81	32 Ge 2.01	33 As 2.18	34 Se 2.55	35 Br 2.96
37 Rb 0.82	38 Sr 0.95	39 Y 1.22	40 Zr 1.33	41 Nb 1.6	42 Mo 2.16	43 Tc 2.10	44 Ru 2.2	45 Rh 2.28	46 Pd 2.20	47 Ag 1.93	48 Cd 1.69	49 In 1.78	50 Sn 1.96	51 Sb 2.05	52 Te 2.1	53 I 2.66
55 Cs 0.79	56 Ba 0.89	57 La 1.10	72 Hf 1.3	73 Ta 1.5	74 W 1.7	75 Re 1.9	76 Os 2.2	77 Ir 2.2	78 Pt 2.2	79 Au 2.4	80 Hg 1.9	81 Tl 1.8	82 Pb 1.8	83 Bi 1.9	84 Po 2.0	85 At 2.2
87 Fr 0.7	88 Ra 0.9	89 Ac 1.1														

Image Bank

Table 8.7	EN Difference and Bond Character
Electronegativity Difference	**Bond Character**
> 1.7	mostly ionic
0.4 – 1.7	polar covalent
< 0.4	mostly covalent
0	nonpolar covalent

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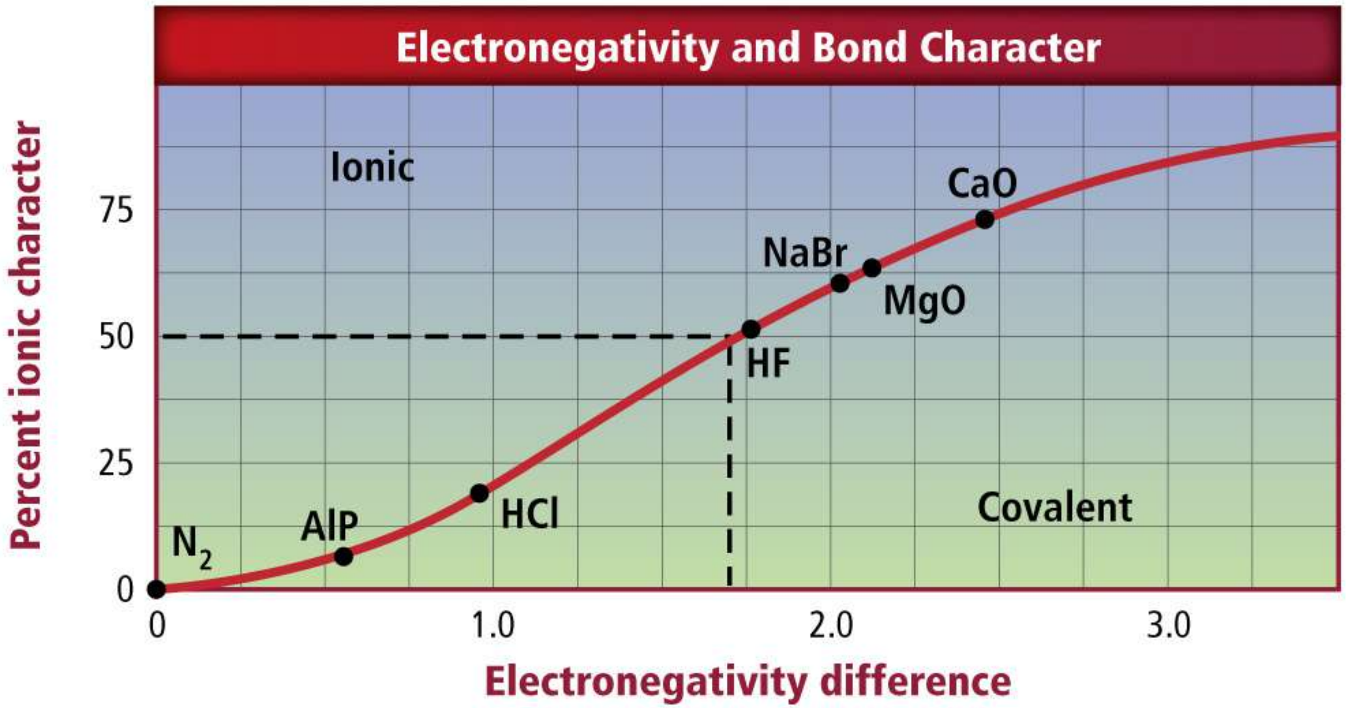
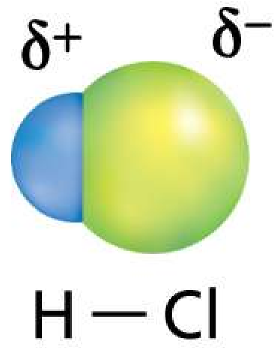

Electronegativity and Bond Character
Percent ionic character
75
50
25
0
Ionic
Covalent
CaO
NaBr
MgO
HF
HCl
AlP
N2
0
1.0
2.0
3.0
Electronegativity difference

Image Bank

$$\text{Electronegativity}\,\text{Cl} = 3.16$$
$$\text{Electronegativity}\,\text{H} = 2.20$$
$$\text{Difference} = 0.96$$



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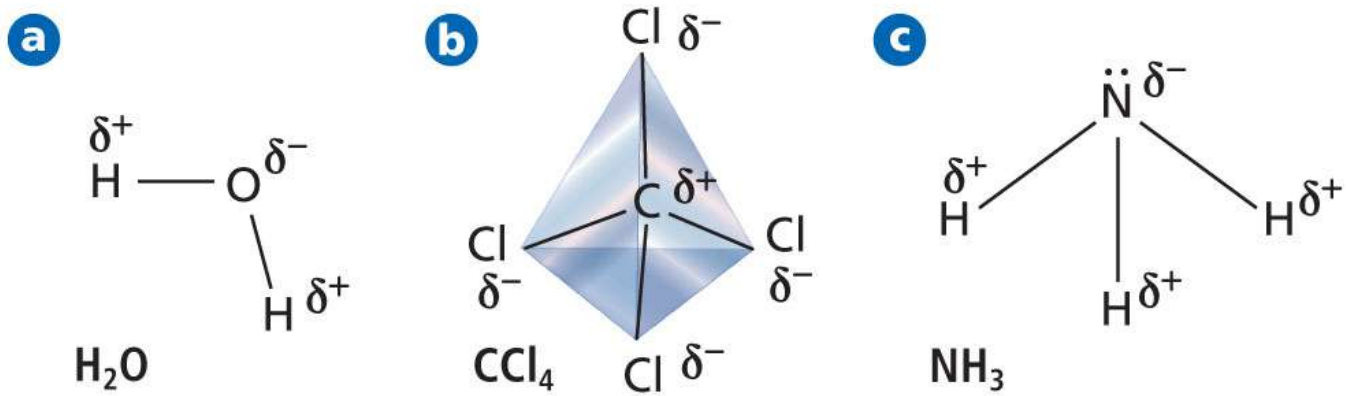

The bent shape of a water molecule makes it polar.

The symmetry of a CCl_4 molecule results in an equal distribution of charge, and the molecule is nonpolar.

The asymmetric shape of an ammonia molecule results in an unequal charge distribution and the molecule is polar.

Concepts In Motion

Figure 8.9 Sigma and Pi Bonding

Table 8.3 Prefixes in Covalent Compounds

Table 8.5 Formulas and Names of Some Covalent Compounds

Figure 8.19 Molecular Shapes

Table 8.6 Molecular Shapes

Figure 8.22 Bond Types

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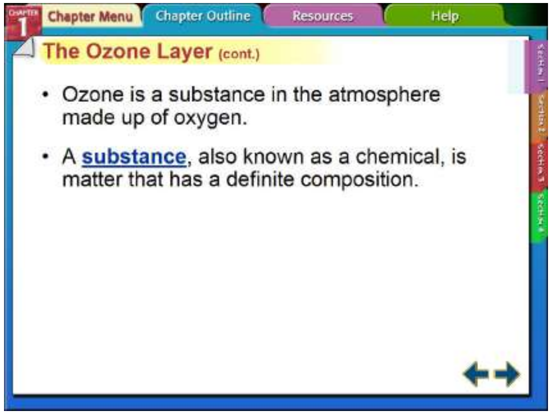

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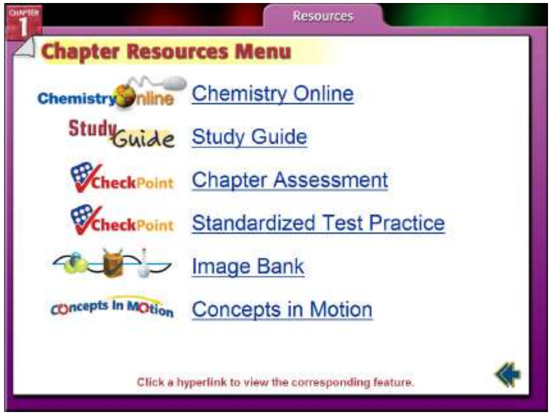

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