

4.E: Covalent Bonding and Simple Molecular Compounds (Exercises)

4.1: Covalent Bonds

Concept Review Exercises

1. How is a covalent bond formed between two atoms?
2. How does covalent bonding allow atoms in group 6A to satisfy the octet rule?

Answers

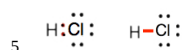
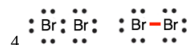
1. Covalent bonds are formed by two atoms sharing electrons.
2. The atoms in group 6A make two covalent bonds.

Exercises

1. Define *covalent bond*.
2. What is electron sharing?
3. Draw the Lewis diagram for the covalent bond in the H_2 molecule.
4. Draw the Lewis diagram for the covalent bond in the Br_2 molecule.
5. Draw the Lewis diagram for the covalent bond in the HCl molecule.
6. What is the difference between a molecule and a formula unit?
7. Why do hydrogen atoms not follow the octet rule when they form covalent bonds?
8. Draw the Lewis diagram for the covalent bonding in H_2S . How many bonding electrons and nonbonding electrons are in the molecule?
9. Draw the Lewis diagram for the covalent bonding in CF_4 . How many bonding electrons and nonbonding electrons are in the molecule?
10. Draw the Lewis diagram for the covalent bonding in PCl_3 . How many bonding electrons and nonbonding electrons are in the molecule?
11. How many covalent bonds does a hydrogen atom typically form? Why?
12. How many covalent bonds does an oxygen atom typically form? Why?
13. Tellurium atoms make covalent bonds. How many covalent bonds would a tellurium atom make? Predict the formula of a compound between tellurium and hydrogen.
14. Tin atoms make covalent bonds. How many covalent bonds would a tin atom make? Predict the formula of a compound between tin and hydrogen.
15. Astatine is a synthetic element, made one atom at a time in huge "atom-smasher" machines. It is in the halogen group on the periodic table. How many covalent bonds would an atom of this element form?
16. There have been reports that atoms of element 116 (Lv) were made by smashing smaller atoms together. Using the periodic table, determine what column element 116 would be in and suggest how many covalent bonds an atom of this element would form.

Answers

1. A covalent bond is formed when two atoms share electrons.
2. Electron sharing joins two atoms in a covalent bond. This is a more stable arrangement than 2 individual atoms.



6. A molecule is a discrete combination of atoms; a formula unit is the lowest ratio of ions in a crystal. 7. Hydrogen atoms follow the duet rule (not the octet rule). This is because it has only one shell and this shell can only hold 2 electrons.

8.



bonding electrons: 4; nonbonding electrons: 4

9.



bonding electrons: 8; nonbonding electrons: 24

10.



bonding electrons: 6; nonbonding electrons: 20

11. Hydrogen atoms form only one covalent bond because they have only one valence electron to pair.
12. Oxygen atoms form 2 covalent bonds because oxygen atoms have 6 valence electrons (2 lone pairs plus 2 unpaired electrons that are shared to achieve octet).
13. two; H_2Te
14. four; SnH_4
15. one
16. two

4.2: Covalent Compounds - Formulas and Names

Concept Review Exercises

1. How do you recognize a covalent compound?
2. What are the rules for writing the molecular formula of a simple covalent compound?
3. What are the rules for naming a simple covalent compound?

Answers

1. A covalent compound is usually composed of two or more nonmetal elements.
2. It is just like an ionic compound except that the element further down and to the left on the periodic table is listed first and is named with the element name.
3. Name the first element first and then the second element by using the stem of the element name plus the suffix -ide. Use numerical prefixes if there is more than one atom of the first element; always use numerical prefixes for the number of atoms of the second element.

Exercises

1. Identify whether each compound has covalent bonds.
 - a. NaI
 - b. Na_2CO_3
 - c. N_2O
 - d. SiO_2
2. Identify whether each compound has covalent bonds.
 - a. C_2H_6
 - b. $\text{C}_6\text{H}_5\text{Cl}$
 - c. $\text{KC}_2\text{H}_3\text{O}_2$
 - d. $\text{Ca}(\text{OH})_2$
3. Identify whether each compound has ionic bonds, covalent bonds, or both.
 - a. Na_3PO_4
 - b. K_2O
 - c. COCl_2
 - d. CoCl_2
4. Identify whether each compound has ionic bonds, covalent bonds, or both.
 - a. FeCl_3
 - b. $\text{Fe}(\text{NO}_3)_3$
 - c. $(\text{NH}_2)_2\text{CO}$
 - d. SO_3
5. Which is the correct molecular formula— H_4Si or SiH_4 ? Explain.
6. Which is the correct molecular formula— SF_6 or F_6S ? Explain.
7. Write the name for each covalent compound.
 - a. SiF_4
 - b. NO_2
 - c. CS_2
 - d. P_2O_5
8. Write the name for each covalent compound.
 - a. CO
 - b. S_2O_3
 - c. BF_3
 - d. GeS_2
9. Write the formula for each covalent compound.
 - a. iodine trichloride
 - b. disulfur dibromide
 - c. arsenic trioxide
 - d. xenon hexafluoride
10. Write the formula for each covalent compound.
 - a. boron trichloride
 - b. carbon dioxide
 - c. tetraphosphorus decoxide
 - d. germanium dichloride
11. Write two covalent compounds that have common rather than systematic names.
12. What is the name of the simplest organic compound? What would its name be if it followed the nomenclature for binary covalent compounds?

Answers

1.
 - a. no
 - b. yes
 - c. yes
 - d. yes
2.
 - a. yes
 - b. yes
 - c. yes
 - d. yes
3. a. both

- b. ionic
 - c. covalent
 - d. ionic
- 4.
- a. ionic
 - b. both
 - c. covalent
 - d. covalent
5. SiH_4 ; except for water, hydrogen is almost never listed first in a covalent compound.
6. SF_6 ; the less electronegative atom (S) is written first
- 7.
- a. silicon tetrafluoride
 - b. nitrogen dioxide
 - c. carbon disulfide
 - d. diphosphorus pentoxide
- 8.
- a. carbon monoxide
 - b. disulfur trioxide
 - c. boron trifluoride
 - d. germanium disulfide
- 9.
- a. ICl_3
 - b. S_2Br_2
 - c. AsO_3
 - d. XeF_6
- 10.
- a. BCl_3
 - b. CO_2
 - c. P_4O_{10}
 - d. GeCl_2
11. H_2O and NH_3 (water and ammonia) (answers will vary)
12. CH_4 ; carbon tetrahydride

4.3: Drawing Lewis Structures

Exercises

- What is one clue that a molecule has a multiple bond?
- Draw the Lewis diagram for each of the following.
 - H_2O
 - NH_3
 - C_2H_6
 - CCl_4
- Each molecule contains double bonds. Draw the Lewis diagram for each. The first element is the central atom.
 - CS_2
 - C_2F_4
 - COCl_2
- Each molecule contains multiple bonds. Draw the Lewis diagram for each. Assume that the first element is the central atom, unless otherwise noted.
 - N_2
 - CO
 - HCN (The carbon atom is the central atom.)
 - POCl (The phosphorus atom is the central atom.)
- Explain why hydrogen atoms do not form double bonds.
- Why is it incorrect to draw a double bond in the Lewis diagram for MgO ?

Answers

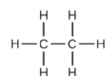
- If single bonds between all atoms do not give all atoms (except hydrogen) an octet, multiple covalent bonds may be present.
- a.



b.



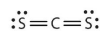
c.



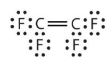
d.



3. a.



b.



c.

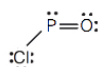


4. a. $\text{:}\ddot{\text{N}}\equiv\ddot{\text{N}}\text{:}$

b. $\text{:}\text{C}\equiv\text{O}\text{:}$

c. $\text{H}\text{:}\text{C}\equiv\ddot{\text{N}}\text{:}$

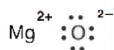
d.



5. Hydrogen can accept only one more electron; multiple bonds require more than one electron pair to be shared.

6. MgO is an ionic compound (Mg transfers two electrons to O). The electrons are not shared hence it's incorrect to draw a double bond.

This is the Lewis dot structure of MgO.



4.4: Characteristics of Covalent Bonds

Concept Review Exercises

1. What is the name for the distance between two atoms in a covalent bond?
2. What does the electronegativity of an atom indicate?
3. What type of bond is formed between two atoms if the difference in electronegativities is small? Medium? Large?

Answers

1. bond length
2. Electronegativity is a qualitative measure of how much an atom attracts electrons in a covalent bond.
3. nonpolar; polar; ionic

Exercises

1. Which is longer—a C–H bond or a C–O bond? (Refer to Table 4.E. 1.)
2. Which is shorter—an N–H bond or a C–H bond? (Refer to Table 4.E. 1.)
3. A nanometer is 10^{-9} m. Using the data in Table 4.E. 1 and Table 4.E. 2, determine the length of each bond in nanometers.
 - a. a C–O bond
 - b. a C=O bond
 - c. an H–N bond
 - d. a C≡N bond
4. An angstrom (Å) is defined as 10^{-10} m. Using Table 4.E. 1 and Table 4.E. 2, determine the length of each bond in angstroms.
 - a. a C–C bond
 - b. a C=C bond
 - c. an N≡N bond
 - d. an H–O bond
5. Refer to Exercise 3. Why is the nanometer unit useful as a unit for expressing bond lengths?
6. Refer to Exercise 4. Why is the angstrom unit useful as a unit for expressing bond lengths?
7. Using Figure 4.E. 3, determine which atom in each pair has the higher electronegativity.
 - a. H or C
 - b. O or Br
 - c. Na or Rb
 - d. I or Cl
8. Using Figure 4.E. 3, determine which atom in each pair has the lower electronegativity.
 - a. Mg or O
 - b. S or F
 - c. Al or Ga
 - d. O or I
9. Will the electrons be shared equally or unequally across each covalent bond? If unequally, to which atom are the electrons more strongly drawn?

- a. a C–O bond
 - b. an F–F bond
 - c. an S–N bond
 - d. an I–Cl bond
10. Will the electrons be shared equally or unequally across each covalent bond? If unequally, to which atom are the electrons more strongly drawn?
- a. a C–C bond
 - b. a S–Cl bond
 - c. an O–H bond
 - d. an H–H bond
11. Arrange the following bonds from least polar to most polar: H-F, H-N, H-O, H-C
12. Arrange the following bonds from least polar to most polar: C-F, C-N, C-O, C-C

Answers

1. A C–O bond is longer.
2. An H–N bond is shorter than an H–C bond.
3. a. 0.143 nm
b. 0.120 nm
c. 0.100 nm
d. 0.116 nm
4. a. 1.54 Å
b. 1.34 Å
c. 1.10 Å
d. 0.97 Å
5. Actual bond lengths are very small, so the nanometer unit makes the expression of length easier to understand.
6. Actual bond lengths are very small, so the angstrom unit makes the expression of length easier to understand.
7. a. C
b. O
c. Na
d. Cl
8. a. Mg
b. S
c. Al
d. I
9. a. unequally toward the O
b. equally
c. unequally toward the N
d. unequally toward the Cl
10. a. equally
b. unequally toward the Cl
c. unequally toward the O
d. equally
11. The electronegativity difference increases from 0.4; 0.9; 1.4; 1.9. Hence, the least to most polar: H-C, H-N, H-O, H-F
12. The electronegativity difference increases from 0; 0.5; 1.0; 1.5. Hence, the least to most polar: C-C, C-N, C-O, C-F

4.5: Characteristics of Molecules

Concept Review Exercises

1. How do you determine the molecular mass of a covalent compound?
2. How do you determine the shape of a molecule?
3. How do you determine whether a molecule is polar or nonpolar?

Answers

1. The molecular mass is the sum of the masses of the atoms in the formula.
2. The shape of a molecule is determined by the position of the atoms, which in turn is determined by the repulsion of the bonded and lone electron pairs around the central atom.
3. If all the bonds in a molecule are nonpolar, the molecule is nonpolar. If it contains identical polar bonds that are oriented symmetrically opposite each other (linear, trigonal planar or tetrahedral) then the molecule is nonpolar. If it contains polar bonds that don't cancel each other's effects, the molecule is polar.

Exercises

1. What is the molecular mass of each compound?
 - a. H_2S
 - b. N_2O_4
 - c. ICl_3
 - d. HCl
2. What is the molecular mass of each compound?
 - a. O_2F_2
 - b. CCl_4

- C_6H_6
 - SO_3
- Aspirin ($C_9H_8O_4$) is a covalent compound. What is its molecular mass?
 - Cholesterol ($C_{27}H_{46}O$) is a biologically important compound. What is its molecular mass?
 - What is the shape of each molecule? State whether it is polar or nonpolar.
 - H_2S
 - $COCl_2$
 - SO_2
 - What is the shape of each molecule? State whether it is polar or nonpolar.
 - NBr_3
 - SF_2
 - SiH_4
 - Predict the shape of nitrous oxide (N_2O), which is used as an anesthetic. A nitrogen atom is in the center of this three-atom molecule. Is this polar?
 - Predict the shape of acetylene (C_2H_2), which has the two carbon atoms in the middle of the molecule with a triple bond. What generalization can you make about the shapes of molecules that have more than one central atom?

Answers

- 34.08 amu
 - 92.02 amu
 - 233.25 amu
 - 36.46 amu
- What is the molecular mass of each compound?
 - 70.00 amu
 - 153.81 amu
 - 78.12 amu
 - 80.06 amu
- 180.17 amu
- 386.73 amu
- bent; polar
 - trigonal planar; nonpolar
 - bent; polar
- pyramidal; polar
 - bent; polar
 - tetrahedral; nonpolar
- linear; polar
- linear; in a molecule with more than one central atom, the geometry around each central atom needs to be examined.

4.6: Organic Chemistry

Concept Review Exercises

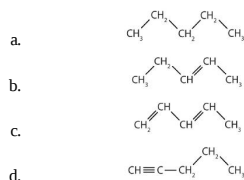
- What is organic chemistry?
- What is a functional group? Give at least two examples of functional groups.

Answers

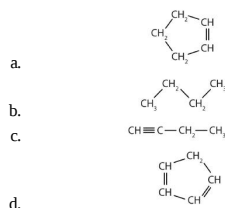
- Organic chemistry is the study of the chemistry of carbon compounds.
- A functional group is a specific structural arrangement of atoms or bonds that imparts a characteristic chemical reactivity to the molecule; alcohol group and carboxylic group (answers will vary).

Exercises

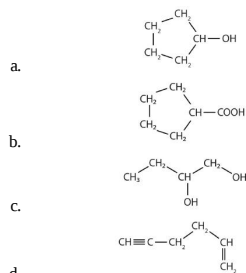
- Give three reasons why carbon is the central element in organic chemistry.
- Are organic compounds based more on ionic bonding or covalent bonding? Explain.
- Identify the type of hydrocarbon in each structure.



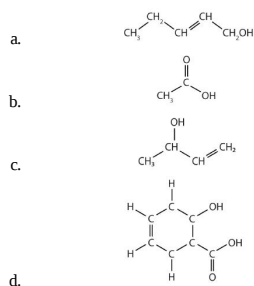
- Identify the type of hydrocarbon in each structure.



5. Identify the functional group(s) in each molecule.



6. Identify the functional group(s) in each molecule.



7. How many functional groups described in this section contain carbon and hydrogen atoms only? Name them.

8. What is the difference in the ways the two oxygen atoms in the carboxyl group are bonded to the carbon atom?

Answers

- Carbon atoms bond reasonably strongly with other carbon atoms. Carbon atoms bond reasonably strongly with atoms of other elements. Carbon atoms make a large number of covalent bonds (four).
- Organic compounds are based on covalent bonding or electron sharing. The atoms C, H, O, N that make up organic compounds are all nonmetals.
- alkane
 - alkene
 - alkene
 - alkyne
- alkene
 - alkane
 - alkyne
 - alkene
- alcohol
 - carboxyl
 - alcohol
 - alkene and alkyne
- a carbon-carbon double bond and alcohol
 - carboxyl group
 - carbon-carbon double bond and alcohol
 - carbon-carbon double bond; alcohol and carboxyl group
- two; carbon-carbon double bonds and carbon-carbon triple bonds
- There are two oxygen atoms in a carboxyl group: one is double-bonded while the other is OH, single bonded to the same carbon atom.

Additional Exercises

Use the atomic masses found in Figure 2.7.1

- An atomic mass unit equals 1.661×10^{-24} g. What is the mass in grams of each molecule of (a) H_2S (b) N_2O_4 (c) ICl_3 (d) NCl_3 ?
- An atomic mass unit equals 1.661×10^{-24} g. What is the mass in grams of (a) O_2F_2 (b) CCl_4 (c) C_6H_6 (d) SO_3 ?
- An atomic mass unit equals 1.661×10^{-24} g. What is the mass in grams of 5.00×10^{22} molecules of $\text{C}_9\text{H}_8\text{O}_4$?
- An atomic mass unit equals 1.661×10^{-24} g. What is the mass in grams of 1.885×10^{20} molecules of $\text{C}_{27}\text{H}_{46}\text{O}$?
- Acetic acid has the following structure:

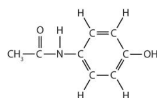


This molecule can lose a hydrogen ion (H^+) and the resulting anion can combine with other cations, such as Na^+ :



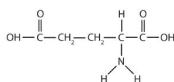
Name this ionic compound.

- Formic acid (HCOOH) loses a hydrogen ion to make the formate ion (HCOO^-). Write the formula for each ionic compound: potassium formate, calcium formate, and ferric formate.
- Cyanogen has the formula C_2N_2 . Propose a bonding scheme that gives each atom the correct number of covalent bonds. (Hint: the two carbon atoms are in the center of a linear molecule.)
- How many carbon-carbon single bonds, linked together, are needed to make a carbon chain that is 1.000 cm long?
- How many carbon-carbon double bonds, linked together, are needed to make a carbon chain that is 1.000 cm long?
- In addition to themselves, what other atoms can carbon atoms bond with and make covalent bonds that are nonpolar (or as nonpolar as possible)?
- What is the greatest possible electronegativity difference between any two atoms? Use Figure 4.4 to find the answer.
- Acetaminophen, a popular painkiller, has the following structure:



Name the recognizable functional groups in this molecule. Do you think there are other groups of atoms in this molecule that might qualify as functional groups?

- Glutamic acid is the parent compound of monosodium glutamate (known as MSG), which is used as a flavor enhancer. Glutamic acid has the following structure:



Name the functional groups you recognize in this molecule. Do you think there are other groups of atoms in this molecule that might qualify as functional groups?

Answers

- $5.661 \times 10^{-23} \text{ g}$
 - $1.528 \times 10^{-22} \text{ g}$
 - $3.874 \times 10^{-22} \text{ g}$
 - $1.999 \times 10^{-22} \text{ g}$
- $1.163 \times 10^{-22} \text{ g}$
 - $2.555 \times 10^{-22} \text{ g}$
 - $1.298 \times 10^{-22} \text{ g}$
 - $1.330 \times 10^{-22} \text{ g}$
- 14.96 g
- 0.1211 g
- sodium acetate
- KHCOO
 - $\text{Ca}(\text{HCOO})_2$
 - $\text{Fe}(\text{HCOO})_3$
- $\text{:N}\equiv\text{C}-\text{C}\equiv\text{N:}$
- $6.49 \times 10^7 \text{ C-C bonds}$
- $7.46 \times 10^7 \text{ C=C bonds}$
- Hydrogen atoms make relatively nonpolar bonds with carbon atoms.
- The greatest electronegativity difference is 3.2, between F and Rb.
- alcohol; the ring with double bonds, and the $\text{O}=\text{C}-\text{NH}$ are also likely functional groups.
- carboxyl and $-\text{NH}_2$ functional groups

Additional Questions

- An atomic mass unit equals $1.661 \times 10^{-24} \text{ g}$. What is the mass in grams of each molecule of (a) H_2S (b) N_2O_4 (c) ICl_3 (d) NCl_3 ?
- An atomic mass unit equals $1.661 \times 10^{-24} \text{ g}$. What is the mass in grams of (a) O_2F_2 (b) CCl_4 (c) C_6H_6 (d) SO_3 ?
- An atomic mass unit equals $1.661 \times 10^{-24} \text{ g}$. What is the mass in grams of 5.00×10^{22} molecules of $\text{C}_9\text{H}_8\text{O}_4$?
- An atomic mass unit equals $1.661 \times 10^{-24} \text{ g}$. What is the mass in grams of 1.885×10^{20} molecules of $\text{C}_{27}\text{H}_{46}\text{O}$?
- Acetic acid has the following structure:



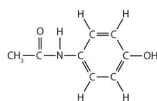
This molecule can lose a hydrogen ion (H^+) and the resulting anion can combine with other cations, such as Na^+ :



Name this ionic compound.

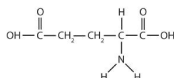
- Formic acid (HCOOH) loses a hydrogen ion to make the formate ion (HCOO^-). Write the formula for each ionic compound: potassium formate, calcium formate, and ferric formate.
- Cyanogen has the formula C_2N_2 . Propose a bonding scheme that gives each atom the correct number of covalent bonds. (Hint: the two carbon atoms are in the center of a linear molecule.)

8. The molecular formula C_3H_6 represents not only propene, a compound with a carbon-carbon double bond, but also a molecule that has all single bonds. Draw the molecule with formula C_3H_6 that has all single bonds.
9. How many carbon-carbon single bonds, linked together, are needed to make a carbon chain that is 1.000 cm long?
10. How many carbon-carbon double bonds, linked together, are needed to make a carbon chain that is 1.000 cm long?
11. In addition to themselves, what other atoms can carbon atoms bond with and make covalent bonds that are nonpolar (or as nonpolar as possible)?
12. What is the greatest possible electronegativity difference between any two atoms? Use Figure 4.4 to find the answer.
13. Acetaminophen, a popular painkiller, has the following structure:



Name the recognizable functional groups in this molecule. Do you think there are other groups of atoms in this molecule that might qualify as functional groups?

14. Glutamic acid is the parent compound of monosodium glutamate (known as MSG), which is used as a flavor enhancer. Glutamic acid has the following structure:



Name the functional groups you recognize in this molecule. Do you think there are other groups of atoms in this molecule that might qualify as functional groups?

Answers

1. 1a: 5.75×10^{-23} g; 1b: 1.53×10^{-22} g; 1c: 3.88×10^{-22} g; 1d: 6.06×10^{-23} g
3. 14.96 g
5. sodium acetate
7. $N \equiv C - C \equiv N$
9. 6.49×10^7 bonds
11. Hydrogen atoms make relatively nonpolar bonds with carbon atoms.
13. alcohol; the N-H group, the ring with double bonds, and the C=O are also likely functional groups.

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