Introduction to Bonding: Two-Dimensional Lewis Structures

Key Terms:

abbreviated electron configuration – combines the inert, noble core electrons (abbreviated via a noble element) with the outermost or valence electrons allowing the student to quickly deduce the number of valence electrons.

Cahn-Ingold Prelog sequence rules – a set of rules which allow one to deduce groups of priority on double bonds or stereocenters, which is usually deduced via differences of molecular weights.

***cis* and *trans* isomer** - when we draw an imaginary line along the axis of the double bond and then compare groups on each carbon using the Cahn-Ingold Prelog sequence rules, we can determine if the groups of priority are on the same side, called the *cis* isomer, often abbreviated Z. Alternatively, the groups of priority can be on opposite sides of the imaginary line called the *trans* isomer, often abbreviated E.

constitutional isomer – when two structures share the same molecular formula but different gross connectivity they are called constitutional or structural isomers. In addition, constitutional isomers have different chemical and physical properties.

covalent bond – when two atoms share a pair of electrons in an attempt to gain stability. The difference of electronegativity values between these two atoms should not exceed 2.1 or a transfer of electron(s) will occur leading to an ionic bond.

double bond – when two pairs of electrons are shared between two atoms (a total of four electrons).

duet rule – When a hydrogen atom has two electrons giving it full valency we say that the atom has adopted the electron configuration of helium; sometimes called the duet rule.

electron configuration – indicates where all the electrons are located for an atom; the principle quantum number, the orbital, and how many electrons are in each orbital via superscripts.

electronegativity - an atoms ability to attract electrons within a chemical bond.

full valency - a term often employed when an atom has gained electrons to become isoelectronic with a noble element; usually adhering to the octet or duet rule.

geometric isomers - have the same gross connectivity but differ only how the groups are oriented in space due to hindered rotation about the doubly-bonded carbons. In addition, geometric isomers also have different chemical and physical properties.

inert – unreactive, not involved in bond making or breaking.

ionic bond – when a positively charged ion (cation) and a negativiely charged ion (anion) are attracted to each other to form a neutral aggregate.

Lewis diagrams - a convenient way to indicate the gross connectivity of atoms within a molecule that utilizes covalent bonds.

noble core electrons – a set of electrons that are isoelectronic with a noble element. Because these inner-core electrons are not involved in bond making or breaking they are normally abbreviated as a noble element (in brackets) for convenience.

octet rule – when an atom has eight electrons around it, sometimes called the octet rule, it has adopted the electron configuration of a stable, noble element.

polar covalent bond – when electrons are not shared equally due to one atom having a greater electronegativity value than the other (ΔEN = 0.4-2.1).

single bond – when only one pair of electrons is shared between two atoms (also see covalent bond).

structural isomer – see constitutional isomer.
triple bond – when three pairs of electrons (a total of six electrons) are shared between two atoms (also see covalent bond).
valence electrons – the outermost electrons involved in bond making and bond breaking.

Chapter One Questions:

1) What is the simplest definition for a chemical bond?
2) What are the two distinct ways that atoms can interact to form bonds?
3) Please define electronegativity and what is the general trend observed on the periodic table for electronegativity values?
4) What is the simplest explanation for why ionic compounds form?
5) How do we know if an ionic bond or a covalent bond will form given a molecular formula?
6) Please predict the ratio of elements (the empirical formula) for the ionic compounds formed from the following pairs of atoms:
   A) K and O
   B) Mg and Cl
7) By examining the electronegativity difference of atoms we can predict when a covalent bond will form. But why will a covalent bond form at all?
8) It is more convenient to represent a covalent bond between two atoms as a "line." What does the "line" represent?
9) Please list the three general types of bonds that can form and indicate the relationship between electronegativity values for each type of these bonds.
10) Please comment on the sharing of the two electrons when a polar covalent bond is formed and include terms such as shielding and deshielding within your explanation.

Chapter One Answers:

1) The simplest definition for a chemical bond is forces that hold atoms together.
2) Either by sharing the outermost electrons, called valence electrons, to form covalent bonds or by transferring valence electrons from one atom to another to form ionic bonds.
3) Electronegativity is defined as an atoms ability to attract electrons within a chemical bond. The noble elements don't have electronegativity values due to the fact that they don't form bonds. The values for electronegativity tend to decrease going right to left and down a family or group as you move away from fluorine.
4) Simply stated, atoms want to adopt the electron configuration of a noble element and they will do this by gaining or losing electrons.
5) To predict what type of bond will form we need to examine the difference of electronegativity values between the atoms. If a difference of approximately 2.1 or greater is calculated between the two atoms then an ionic bond will form, which is typical for a metal and a nonmetal, and if a difference less than 2.1 is calculated between two atoms then a covalent bond will form.
6) A) K_2O B) $MgCl_2$
7) When covalent bonds form electrons are shared between the atoms. When electrons are shared atoms have access to additional electrons allowing the atoms to obtain full valency (or adopt the electron configuration of the nearest noble element).

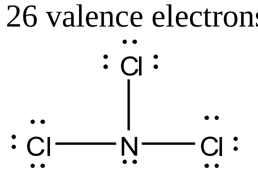
8) The line represents two electrons being shared by each atom.
9) Covalent bond (ΔEN=0.0-0.4), polar covalent bond (ΔEN=0.4-2.1), and ionic bond (ΔEN>2.1).
10) The build-up of electron density on the more electronegative atom causes a partial negative charge, commonly called shielding, and a loss of electron density around the atom with the smaller electronegativity value, commonly called deshielding, results in a partial positive charge. Thus, a polar covalent bond is formed. Often, an arrow indicates a dipole pointing toward the more electronegative element.

Chapter Two Questions:

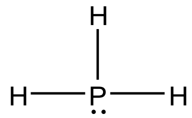
1) What is a Lewis dot diagram for an element?
2) What is a Lewis diagram?
3) Please write the general set of rules that has been developed to guide the student when drawing Lewis structures.
4) Please indicate the number of valence electrons and draw the Lewis diagram for NCl_3.
5) Please indicate the number of valence electrons and draw the Lewis diagram for PH_3.
6) Please indicate the number of valence electrons and draw the Lewis diagram for $CHCl_3$.
7) Please indicate the number of valence electrons and draw the Lewis diagram for HCN (carbon is the central atom).
8) Please indicate the number of valence electrons and draw the Lewis diagram for formaldehyde, H_2CO (carbon is the central atom).
9) Please indicate the number of valence electrons and draw the Lewis diagram for SF_2.
10) Please indicate the number of valence electrons and draw the Lewis diagram for H_2CS (carbon is the central atom).

Chapter Two Answers:

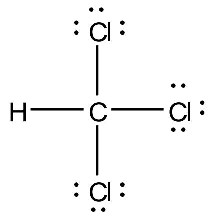
1) A Lewis dot diagram for an element includes only the valence electrons. Examining the element's abbreviated electron configuration allows us to deduce the number of valence electrons present. For most elements of the periodic table we imagine a box around the element. Each side of the box can hold two electrons, which are represented by dots.
2) A Lewis diagram is a convenient way to indicate the gross connectivity of atoms within a molecule that utilizes covalent bonds.
3) Given a molecular formula, count the total number of valence electrons, use two electrons to form a covalent bond between atoms, and then give full valency to the atoms using the remaining electrons, which may require multiple bonds between atoms. Remember, a trial and error approach is often necessary!
4) 26 valence electrons



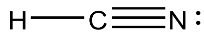
5) 8 valence electrons



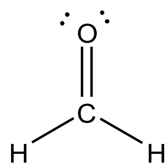
6) 26 valence electrons



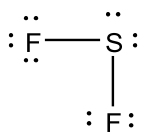
7) 10 valence electrons



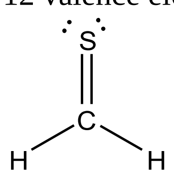
8) 12 valence electrons



9) 20 valence electrons



10) 12 valence electrons

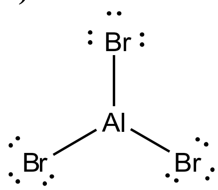


Chapter Three Questions:

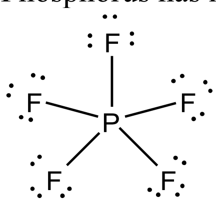
1) Please list the second row elements that will always adhere to the octet rule.
2) Please list the second row elements that can have fewer electrons than the octet rule.
3) Please list two elements from the third row that can follow the octet rule and that are also capable of exceeding eight electrons.
4) Please list two third row elements that can have fewer than eight electrons.
5) Please draw the Lewis structure for $AlBr_3$.
6) Please draw the Lewis structure for PF_5.
7) Please draw the Lewis structure for ICl_4^{-1}.
8) Please draw the Lewis structure for RnF_2.
9) Please draw the Lewis structure for BrF_3.
10) Please draw the Lewis structure for $XeCl_4$.

Chapter Three Answers:

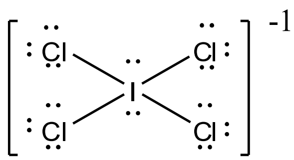
1) The octet rule for second row elements such as carbon, nitrogen, oxygen, and fluorine will always hold and those elements cannot exceed eight electrons.
2) Beryllium and boron can have fewer electrons than an octet.
3) Third row elements such as sulfur and phosphorous can follow the octet rule; however, they can also exceed eight electrons.
4) Magnesium and aluminum can have fewer than eight electrons.
5) Aluminum has less than an octet of electrons (6 electrons).



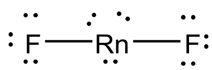
6) Phosphorus has more than an octet of electrons (10 electrons).



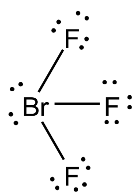
7) Iodine has more than an octet of electrons (12 electrons).



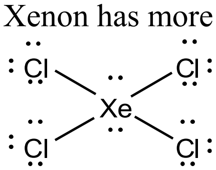
8) Radon has more than an octet of electrons (10 electrons).



9) Bromine has more than an octet of electrons (10 electrons).



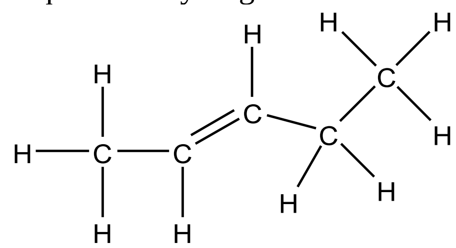
10) Xenon has more than an octet of electrons (12 electrons).



Chapter Four Questions:

1) Please define an organic compound.
2) If atom “X” has five valence electrons, how many covalent bonds will atom “X” form to obtain an octet?

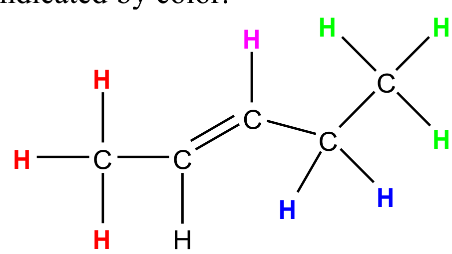
3) Please write the general formulas for a saturated hydrocarbon, a hydrocarbon with one degree of unsaturation, and a hydrocarbon with two degrees of unsaturation. In addition, please indicate how full valency may be satisfied if one or two degrees of unsaturation exist within the given molecular formula.
4) Please identify all of the equivalent hydrogens within the following Lewis structure:



5) Please describe the difference between the *cis* and *trans* geometric isomer.
6) Please draw a pair of geometric isomers for C_4H_8.
7) Please draw as many isomers as possible for C_4H_8.
8) Please draw as many isomers as possible for C_3H_4O.
9) Please draw as many isomers as possible for $C_2H_6S_2$.
10) Please draw as many isomers as possible for $C_3H_{10}N_2$.

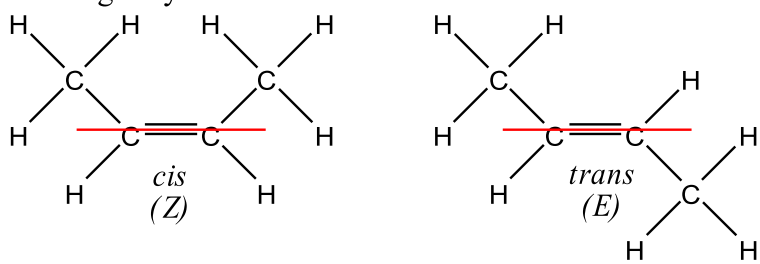
Chapter Four Answers:

1) It is estimated that over half of all known molecules are organic compounds, which means they are carbon based. And virtually all organic compounds are formed from elements that adhere to the octet and duet rule.
2) If atom "X" has five valence electrons it will need three more for an octet. It will gain these three additional electrons by forming three covalent bonds. Remember, each time a bond is formed an atom has access to an additional electron. Thus, if an atom needs n electrons for full valency it will form n bonds.
3) A fully saturated hydrocarbon follows the C_nH_{2n+2} formula, where n is an integer. For one degree of unsaturation the general formula is C_nH_{2n}. If a degree of unsaturation exists one can introduce a double bond or a ring. For two degrees of unsaturation the general formula is C_nH_{2n-2}. Two degrees of unsaturation are satisfied by a triple bond, two double bonds, a double bond and a ring, or two rings (provided there are a minimum of four carbons in the given molecular formula).
4) Equivalent hydrogens are indicated by color.

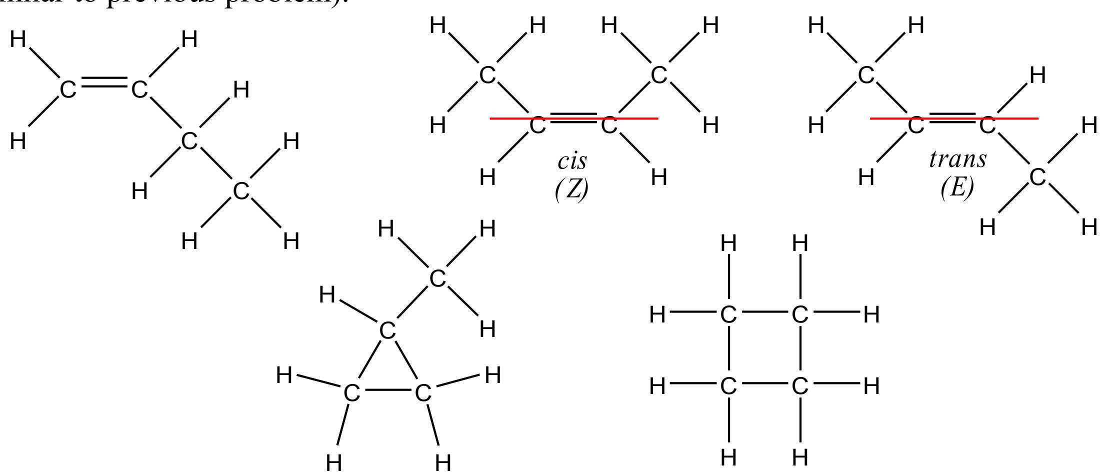


5) If the groups of priority are on the same side of an imaginary line running parallel to the double bond we call this the *cis* isomer, often abbreviated Z. Alternatively, the groups of priority can be on opposite sides of the imaginary line called the *trans* isomer, often abbreviated E. The *cis* and *trans* isomers are isolable due to hindered rotation about the doubly bonded carbons. In addition, the *cis* and *trans* isomers have different chemical and physical properties.

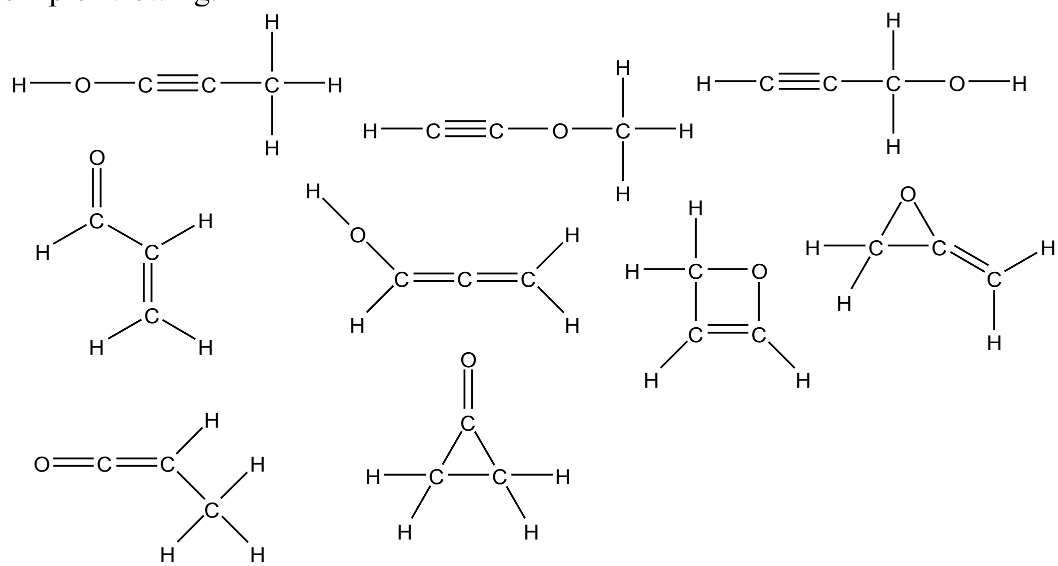
6) The first isomer, the cis (Z), has both groups of priority on the same side of the imaginary line (shown in red), while the trans (Z) isomer has groups of priority on opposite sides of the imaginary line.



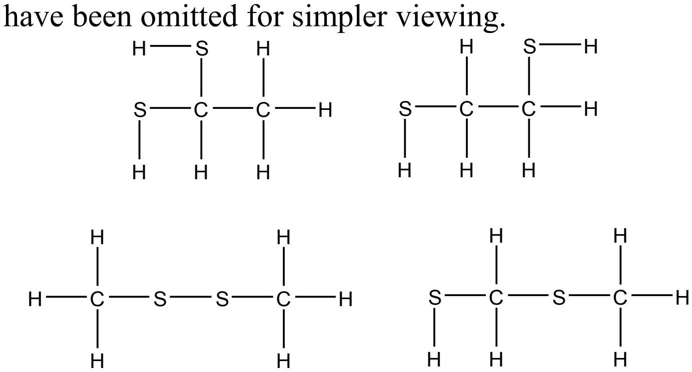
7) There are five isomers possible for C_4H_8 (notice that there is a pair of geometric isomers, similar to previous problem).



8) There are a total of nine structural isomers for C_3H_4O. Notice that all solutions containing a carbon three-member ring with a double bond have been omitted. Although these solutions fit our set of rules they are too strained to exist at room temperature and can be eliminated. In addition, the two lone pairs on the oxygen atom have been omitted for simpler viewing.



9) There are a total of four isomers possible for $C_2H_6S_2$. In addition, the two lone pairs on each sulfur atom have been omitted for simpler viewing.



10) There are a total of thirteen isomers possible for $C_3H_{10}N_2$. In addition, the lone pair on each nitrogen atom has been omitted for simpler viewing.