

Bonding - Review

Covalent Bonding in Molecular Compounds

1. How is the bonding in O_2 different than in MgO ? Give more of an explanation than just the name for the type of bonding in each.
2. Give the name or chemical formula for each of the following substances and in each case predict whether the bonding is better described as ionic or covalent:
 - a) iron(II) fluoride
 - b) chromium(III) oxide
 - c) selenium dibromide
 - d) SF_6
 - e) $CoCl_2$
 - f) $ScBr_3$
 - g) nitrogen dioxide
 - h) hydrogen sulfide
3. What happens when a covalent substance dissolves? When it melts?
4. Why do covalent compounds (in general) have lower melting and boiling points than ionic compounds?

Lewis Structures

5. What is a Lewis structure and how does it differ from a Lewis dot symbol?
6. Construct Lewis structures for F_2 , O_2 , and N_2 in which each atom achieves an octet of electrons. Explain how the covalent bonds differ for each molecule. How many pi and sigma bonds are present in each molecule?
7. Draw Lewis Structures for each of the following molecules and show the number of valence electrons in () below each chemical formula:

a) NCl_5	e) PF_3	i) OF_2
b) N_2O_4	f) CO_3^{2-}	j) O_3
c) CO	g) $C_2H_4(OH)_2$	k) BF_3
d) C_2FH_3	h) ClF_5	l) SO_2
m) HCN	q) HBr	u) NO_2^-
n) $CHCl_3$	r) NH_4^+	v) NO_3^-
o) H_2CO	s) PO_4^{3-}	
p) SeF_2	t) H_3O^+	
8. Draw Lewis structures for the following ions: NO_3^{-1} , PO_4^{-3} , and SO_4^{-2} . Explain why each of these ions is stable with the appropriate charge.
9. Urea, a substance produced in protein metabolism, has a central C atom bonded to an O and two N atoms, NH_2CONH_2 . Draw the Lewis structure for urea.
10. Three different Lewis structures are possible for N_2O . Draw all three. Which one is the best description of the bonding in this molecule? Why?

Molecular Shapes and VSEPR

11. Why is it important to understand and be able to predict the shape of molecules?
12. What factors do you consider in determining the molecular shape of a molecule?
13. What is the VSEPR model for determining molecular shape? What are the limitations of this model?
14. Define:
- | | |
|--------------------|-----------------------|
| a) bonding pair | c) electron geometry |
| b) nonbonding pair | d) molecular geometry |
15. Describe the effect of nonbonding electrons on bond angles. Where do the nonbonding electrons have to be to affect molecular shape?
16. The Lewis Structure for which of the following molecules would have two non-bonded pairs of electrons on the central atom?
- | | | | | |
|-------------------------|------------------|------------------|-----------------|------------------|
| a) H_2S | b) NH_3 | c) CH_4 | d) HCN | e) CO_2 |
|-------------------------|------------------|------------------|-----------------|------------------|
17. For the following descriptions of molecular shape sketch the geometric object on which it is based and sketch a ball and stick drawing of the shape:
- | | |
|-------------------------|---------------------|
| a) trigonal planar | f) octahedral |
| b) tetrahedral | g) seesaw |
| c) trigonal pyramidal | h) t-shaped |
| d) bent | i) square pyramidal |
| e) trigonal bipyramidal | j) square planar |
18. Rank the following VSEPR molecular shapes in order of decreasing bond angle: tetrahedral, linear, pyramidal, and triangular.
19. Use VSEPR theory to predict the shape of each molecule below and predict whether each molecule is polar or non-polar. Identify each molecule's shape by name, indicate the bond angles and the type of hybridization around the central atom(s)
- | | | |
|--|-----------------------------|---------------------------|
| a) PCl_3 | i) I_3^{-1} | p) Sulfuric acid |
| b) N_2O_4 | j) NO | q) Phosphoric acid |
| c) NF_3 | k) XeO_2F_2 | r) Nitric acid |
| d) SO_2 | l) IF_3 | s) Xenon hexafluoride |
| e) $\text{C}_2\text{H}_4(\text{OH})_2$ | m) ClF_5 | t) H_2O_2 |
| f) OF_2 | n) Hydrogen phosphide | u) HClO_4 |
| g) SO_3 | o) Hydrobromic acid | |
| h) BH_3 | | |
20. Describe the difference between a polar covalent bond and a non-polar covalent bond.

21. Which of the following bonds are polar and which is the more electronegative atom in each polar bond? (use the values listed on your periodic table to answer this question)

a) C - Cl

c) P - F

e) Si - Si

b) C - O

d) N - Br

22. Arrange the bonds in each of the following sets in order of increasing polarity:

a) C - F, O - F, Be - F

c) C - S, B - P, N - O

b) N - Br, P - Br, O - Br

23. How does a polar molecule differ from a non-polar one?

Metallic Bonding

24. What is a metallic bond?

25. Explain how the high electrical conductivity of metals is explained by the idea of metallic bonds.

26. If you were given a strange unknown solid what are some ways you could determine if it was an ionic compound or a metal?

Covalent bond characteristics

27. What is a covalent bond? How does it differ from an ionic bond?

28. What is a single covalent bond? Why does it form?

29. Why do multiple bonds (double and triple bonds) form? Explain the formation of multiple bonds in terms of orbital overlap.

30. What is the difference between single, double, and triple bonds in terms of bond strength? Bond length?

31. What are the similarities and differences between the bonding in diamond and graphite? How are these differences in bonding reflected in the properties of the materials?

Characteristics of Ionic compounds/bonds

32. What happens to an ionic compound when it dissolves? When it melts?

33. Why do ionic compounds conduct electricity when dissolved or melted?

34. What holds ionic crystals together?

35. Ionic compounds are generally hard, brittle, and have high melting and boiling points. How can these properties be explained by their bonding?

36. How could you predict that a bond between two elements would be ionic?

Intermolecular Forces

37. What are intermolecular forces?

38. What type of intermolecular forces are present in the following compounds?

a. Water

f. Hydrogen fluoride

b. Ammonia

g. Carbon dioxide

c. Iodine

h. Carbon monoxide

d. Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$)

i. Hexane

e. Hydrogen chloride

($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$)

39. Why do ionic compounds dissolve in polar solvents but not in non-polar solvents?

40. Why does water have a much higher boiling point than H_2S ?

Orbital hybridization

41. What are orbitals?
42. How are hybrid orbitals created?
43. What type of hybridization exists in the central atom(s) in each of the following molecules?
 - a) CO_2
 - b) CH_4
 - c) NH_3
 - d) CH_2O
 - e) HCN
 - f) PCl_5
44. How is a sigma bond formed?
45. What is a pi bond? How is it formed?
46. How many sigma and pi bonds are there in each of the following molecules?
 - a) C_2H_2
 - b) C_2H_4
 - c) N_2H_2
 - d) CO_2

Bonding - Review

Covalent Bonding in Molecular Compounds

1. How is the bonding in O_2 different than in MgO ? Give more of an explanation than just the name for the type of bonding in each.
 O_2 is held together by a covalent bond (electrons shared) and MgO is held together by an ionic bond (transfer of electrons)

2. Give the name or chemical formula for each of the following substances and in each case predict whether the bonding is better described as ionic or covalent:

- | | |
|---|---|
| a) iron(II) fluoride – FeF_2 - ionic | e) $CoCl_2$ – cobalt chloride - ionic |
| b) chromium(III) oxide – Cr_2O_3 - ionic | f) $ScBr_3$ – scandium bromide - ionic |
| c) selenium dibromide – $SeBr_2$ - covalent | g) nitrogen dioxide – NO_2 - covalent |
| d) SF_6 – sulphur hexafluoride - covalent | h) hydrogen sulfide - H_2S - covalent |

3. What happens when a covalent substance dissolves? When it melts?

In each case, intermolecular forces are broken, but molecules remain whole. When a covalent compound dissolves, molecules are solvated (surrounded by solvent molecules)

4. Why do covalent compounds (in general) have lower melting and boiling points than ionic compounds?

Because intermolecular forces/interactions are weaker than ionic or covalent bonds. To melt/boil a covalent compound you only need to break intermolecular forces, but to melt/boil an ionic compound, ionic bonds must be broken which takes a lot of energy

Lewis Structures

5. What is a Lewis structure and how does it differ from a Lewis dot symbol?
Lewis structure is for a molecule, but Lewis dot symbol is only for a single element

6. Construct Lewis structures for F_2 , O_2 , and N_2 in which each atom achieves an octet of electrons. Explain how the covalent bonds differ for each molecule. How many pi and sigma bonds are present in each molecule?

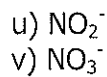
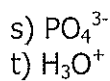
F_2 – single covalent bond, O_2 – double covalent bond, N_2 – triple covalent bond

7. Draw Lewis Structures for each of the following molecules and show the number of valence electrons in () below each chemical formula:

- a) NCl_5
- b) N_2O_4
- c) CO
- d) C_2FH_3
- m) HCN
- n) $CHCl_3$

- e) PF_3
- f) CO_3^{2-}
- g) $C_2H_4(OH)_2$
- h) ClF_5
- o) H_2CO
- p) SeF_2

- i) OF_2
- j) O_3
- k) BF_3
- l) SO_2
- q) HBr
- r) NH_4^+



8. Draw Lewis structures for the following ions: NO_3^{-1} , PO_4^{-3} , and SO_4^{-2} . Explain why each of these ions is stable with the appropriate charge.
9. Urea, a substance produced in protein metabolism, has a central C atom bonded to an O and two N atoms, NH_2CONH_2 . Draw the Lewis structure for urea.
10. Three different Lewis structures are possible for N_2O . Draw all three. Which one is the best description of the bonding in this molecule? Why?

Molecular Shapes and VSEPR

11. Why is it important to understand and be able to predict the shape of molecules?
Molecular shapes affect the properties of the substances (polarity, melting and boiling point, solubility, etc) and help us to explain these properties.
12. What factors do you consider in determining the molecular shape of a molecule?
Number of bonding electron pairs and number of lone pairs
13. What is the VSEPR model for determining molecular shape? What are the limitations of this model?
Valence shell electron pair repulsion. This model predicts shape by explaining that electron pairs repel each other and try to get as far away from each other as possible. In reality, it does not account for all of the factors influencing the shape of a molecule, and makes no predictions about bond length
14. Define:
a) bonding pair – pair of electrons involved in a bond
b) nonbonding pair – pair of electrons on central atom that are not part of a bond
c) electron geometry – arrangement of all electron pairs around the central atom
d) molecular geometry – arrangement of all atoms around the central atom
15. Describe the effect of nonbonding electrons on bond angles. Where do the nonbonding electrons have to be to affect molecular shape?
Non bonding electrons generally have the effect of decreasing the bond angle between the bonding electron pairs. To affect molecular shape, the non-bonding electrons must be on the central atom
16. The Lewis Structure for which of the following molecules would have two non-bonded pairs of electrons on the central atom?
a) H_2S b) NH_3 c) CH_4 d) HCN e) CO_2

17. For the following descriptions of molecular shape sketch the geometric object on which it is based and sketch a ball and stick drawing of the shape:

- | | |
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| a) trigonal planar | f) octahedral |
| b) tetrahedral | g) seesaw |
| c) trigonal pyramidal | h) t-shaped |
| d) bent | i) square pyramidal |
| e) trigonal bipyramidal | j) square planar |

18. Rank the following VSEPR molecular shapes in order of decreasing bond angle: tetrahedral, linear, pyramidal, and triangular. *Linear > trig. Planar (triangular) > tetrahedral > trig. pyramid*

19. Use VSEPR theory to predict the shape of each molecule below and predict whether each molecule is polar or non-polar. Identify each molecule's shape by name, indicate the bond angles and the type of hybridization around the central atom(s)

- | | | |
|--|-----------------------------|---------------------------|
| a) PCl_3 | i) I_3^{-1} | p) Sulfuric acid |
| b) N_2O_4 | j) NO | q) Phosphoric acid |
| c) NF_3 | k) XeO_2F_2 | r) Nitric acid |
| d) SO_2 | l) IF_3 | s) Xenon hexafluoride |
| e) $\text{C}_2\text{H}_4(\text{OH})_2$ | m) ClF_5 | t) H_2O_2 |
| f) OF_2 | n) Hydrogen phosphide | u) HClO_4 |
| g) SO_3 | o) Hydrobromic acid | |
| h) BH_3 | | |

20. Describe the difference between a polar covalent bond and a non-polar covalent bond. *In a polar covalent bond, electrons are unequally distributed, while in a non-polar bond, electron sharing is equal*

21. Which of the following bonds are polar and which is the more electronegative atom in each polar bond? (use the values listed on your periodic table to answer this question)

- | | | |
|-----------|-----------|------------|
| a) C - Cl | c) P - F | e) Si - Si |
| b) C - O | d) N - Br | |

22. Arrange the bonds in each of the following sets in order of increasing polarity:

- a) C - F, O - F, Be - F *Be-F > C-F > O-F*
 b) N - Br, P - Br, O - Br *P-Br > N-Br > O-Br*
 c) C - S, B - P, N - O

23. How does a polar molecule differ from a non-polar one?

Polar molecule has one region of the molecule with a partial positive charge and another region of the molecule with a partial negative charge. In a non-polar molecule, no charges are apparent.

Metallic Bonding

24. What is a metallic bond?

A sea of positive metal nuclei held together by their attraction for the delocalized electrons in between them

25. Explain how the high electrical conductivity of metals is explained by the idea of metallic bonds.

Because delocalized electrons can move, they are able to carry charges and hence conduct electricity

26. If you were given a strange unknown solid what are some ways you could determine if it was an ionic compound or a metal?

Metals would conduct electricity in the solid state while ionic compounds would not

Covalent bond characteristics

27. What is a covalent bond? Electrons are shared How does it differ from an ionic bond? In an ionic bond, electrons are transferred

28. What is a single covalent bond? Sharing of two electrons Why does it form? To fulfill the octet requirements of both atoms involved by sharing two electrons, when two orbitals pointing towards each other overlap.

29. Why do multiple bonds (double and triple bonds) form? *When 4 or 6 electrons are shared.* Explain the formation of multiple bonds in terms of orbital overlap. *Multiple bonds occur when pi bonds form which occur when parallel p orbitals overlap*

30. What is the difference between single, double, and triple bonds in terms of bond strength? Bond length? *Single bonds are weaker than double bonds which are weaker than triple bonds. The pattern for length is that single bonds are longest and triple bonds are the shortest*

31. What are the similarities and differences between the bonding in diamond and graphite? *Both are network covalent solids, but diamond has a 3D structure while graphite has a 2D structure with delocalized electrons in between the covalently bonded layers.* How are these differences in bonding reflected in the properties of the materials? *Because graphite has delocalized electrons it can conduct electricity. Because of the 3D network of covalent bonds in diamond, it is very strong and hard, with a very high melting point.*

Characteristics of Ionic compounds/bonds

32. What happens to an ionic compound when it dissolves? Ions dissociate and are surrounded by solvent molecules When it melts? Ionic bonds are broken and ions move around independently

33. Why do ionic compounds conduct electricity when dissolved or melted? *Ions are mobile and can carry charges. Mobile charge carriers are a requirement for electricity to flow*

34. What holds ionic crystals together? *electrostatic attraction between cations and anions*

35. Ionic compounds are generally hard, brittle, and have high melting and boiling points. How can these properties be explained by their bonding? *ionic compounds are not made of individual molecules but of a lattice of ions that are all bonded to their neighbouring counterions. To break the ions apart requires a lot of energy because the electrostatic attraction between the anions and cations is very strong.*

36. How could you predict that a bond between two elements would be ionic? *If one is a metal and one is a non-metal or if their electronegativity values are very different*

Intermolecular Forces

37. What are intermolecular forces? *Forces acting between different molecules*

38. What type of intermolecular forces are present in the following compounds?

- Water *h - bonds*
- Ammonia *h-bonds*
- Iodine *London/dispersion forces*
- Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) *h -bonds*
- Hydrogen chloride *dipole-dipole interactions*
- Hydrogen fluoride *h - bonds*
- Carbon dioxide *London/dispersion forces*
- Carbon monoxide *dipole-dipole forces*
- Hexane ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$) *London/dispersion forces*

39. Why do ionic compounds dissolve in polar solvents but not in non-polar solvents? *Polar solvents are attracted to the anions and cations in an ionic solid and can solvate the ions effectively. Non-polar solvents are not attracted to the charged particles and they cannot overcome the ionic bonds holding the crystal together*

40. Why does water have a much higher boiling point than H_2S ? *h-bonds*

Orbital hybridization

41. What are orbitals?

Regions where there is a high probability of finding electrons

42. How are hybrid orbitals created?

Combining the mathematical functions that describe 2 or more orbitals together and coming up with a new function that describes a new shape of orbital

43. What type of hybridization exists in the central atom(s) in each of the following molecules?

- | | |
|------------------------------------|--|
| a) CO_2 - sp | d) CH_2O - sp ² |
| b) CH_4 - sp ³ | e) HCN - sp |
| c) NH_3 - sp ³ | f) PCl_5 - sp ³ d |

44. How is a sigma bond formed?

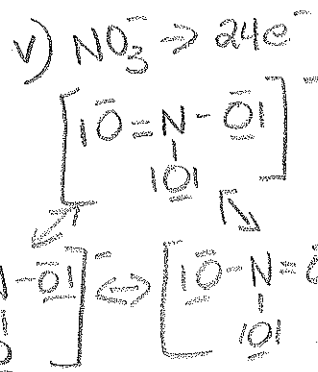
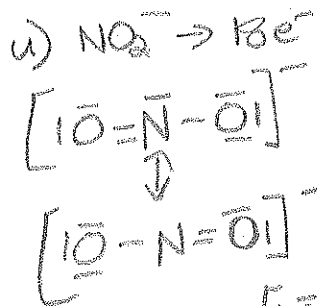
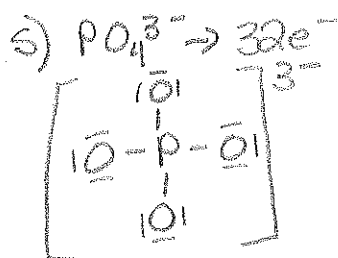
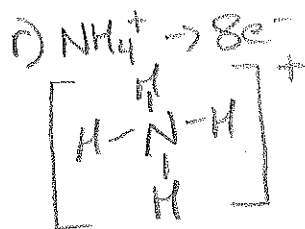
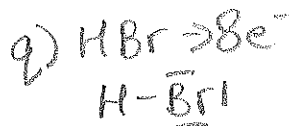
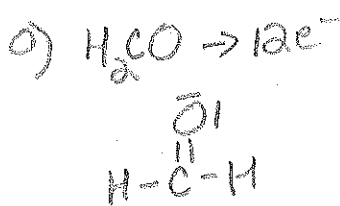
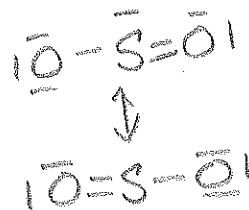
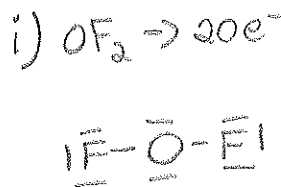
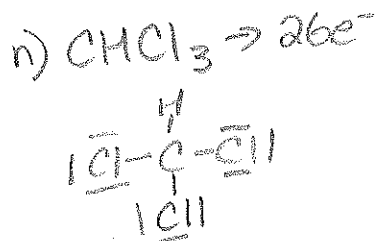
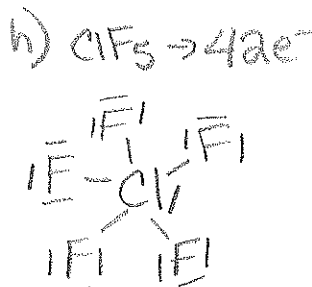
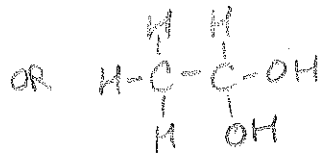
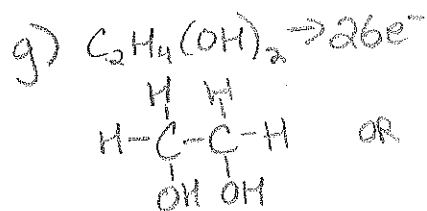
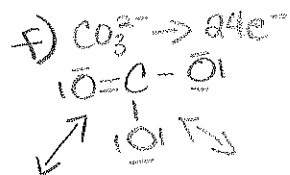
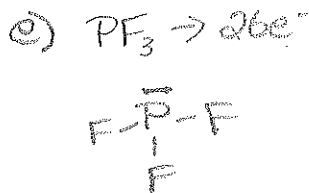
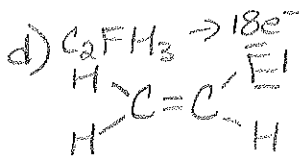
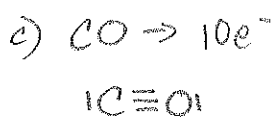
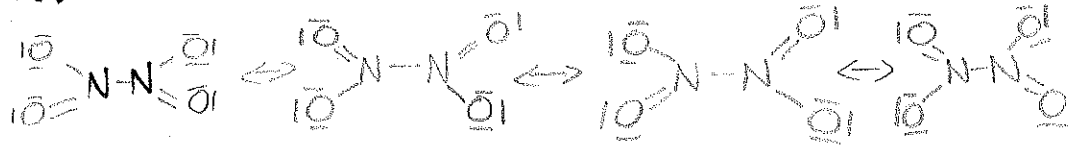
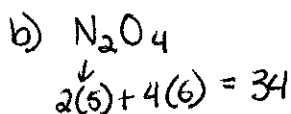
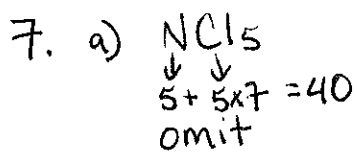
Overlap of two orbitals that are pointed towards each other

45. What is a pi bond? How is it formed?

Bond formed by overlap of two parallel p orbitals.

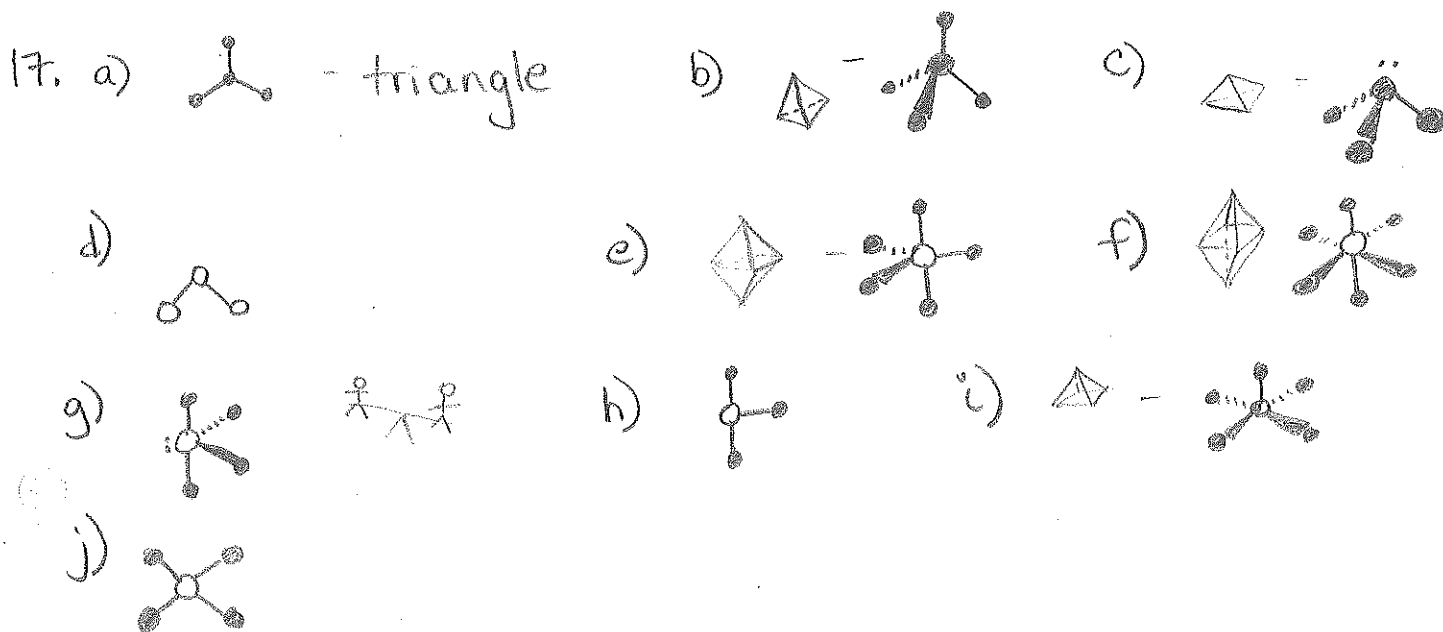
46. How many sigma and pi bonds are there in each of the following molecules?

- | | |
|---|-------------------------------------|
| a) C_2H_2 - 3 sigma, 2 pi | c) N_2H_2 - 5 sigma |
| b) C_2H_4 - 5 sigma, 1 pi | d) CO_2 - 2 sigma, 2 pi |



8. NO_3^- - see # 7, PO_4^{3-} - see # 7, SO_4^{2-} $\left[\begin{array}{c} \text{O} \\ | \\ \text{O}-\text{S}-\text{O} \\ | \\ \text{O} \end{array} \right]^{2-}$
 - with less negative charge, these polyatomic ions could not achieve full octets for all atoms

9. $\text{H}-\text{N}(\text{H})-\text{C}(\text{O})-\text{N}(\text{H})-\text{H}$ 10. $\text{N}_2\text{O} \rightarrow 16e^-$
 $\text{N}=\text{O}=\text{N}$ OR $\text{N}\equiv\text{O}-\text{N}$
 OR $\text{N}-\text{O}\equiv\text{N}$ best picture is probably some blend of all three

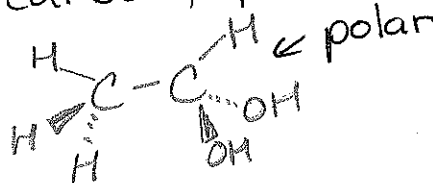


19. a) trigonal pyramid, polar, sp^3 , 107.5°
 b) trig planar around each N, 120° , sp^2 , non-polar
 c) trig pyramid, polar, sp^3 , 107.5°
 d) bent/v-shaped, polar, sp^2 , $\sim 120^\circ$
 e) tetrahedral around each carbon, sp^3 , 109.5°



← non-polar

OR



← polar

f) bent/v-shaped, polar, sp^3 , $\sim 104^\circ$
 g) trig. planar, sp^2 , non-polar, 120°
 h) trig. planar, sp^2 , non-polar, 120°

- i) linear, non polar, 120° , sp
- j) linear, polar - oops, omit, odd # e^- 's
- k) see-saw, polar, sp^3d , complex bond angles
- l) t-shaped, polar, sp^3d , 90° or 180°
- m) square pyramid, polar, sp^3d^2 , 90°
- n) trig. pyramid, polar, sp^3 , 107.5° (H_3P)
- o) linear, polar, Br- sp^3
- p) SO_4^{2-} only \rightarrow tetrahedral, non-polar, sp^3 , 109.5°
- q) PO_4^{3-} only \rightarrow tetrahedral, non-polar, sp^3 , 109.5°
- r) NO_3^- only \rightarrow trig. planar, non-polar, sp^2 , 120°
- s) too many e^- 's on central atom to name the shape
- t) bent around each O, polar, sp^3 , $\sim 104^\circ$
- u) ClO_4^- only \rightarrow tetrahedral, non-polar, sp^3 , 109.5°

