Chapter 8

Bonding

Chapter 9

Covalent Bonding

Name _____

Period _____ Date _____

Introduction to Bonding

Click here to type your definition of a chemical bond and explanation of why most atoms form chemical bonds. Use your own words.

Bonding Comparison Chart

	IONIC	COVALENT	METALLIC
Types of Atoms Involved			
Method of Bond Formation			
Type of Structure			
Physical State			
Melting Point			
Solubility in Water			
Electrical Conductivity			
Other Properties			
Image			

A	B	C	D	E	F	G	H	I
Central Atom electron Pairs	Electron Pair Arrangement	Draw Image	# of Bonding e pairs	# of lone pairs (non-bonding)	Molecular geometry	Draw Image	Bond Angels/ Hybridizatioon	Polarity
2	Linear		2	0	Linear		180° sp	Polar/Non-polar
3	Trigonal Planar		3	0	Trigonal Planar		120° sp^2	Polar/Non-polar
			2	1	Bent		~104.5°	Polar
4	Tetrahedral		4	0	Tetrahedral		109.5° sp^3	Polar/Non-polar
			3	1	Trigonal Pyramid		~109.5°	Polar
			2	2	Bent		~109.5°	Polar
5	Trigonal Bipyramidal		5	0	Trigonal Bypyramid		90° 120° sp^3d	Polar/Non-polar
			4	1	See-Saw		~90° ~120°	Polar
			3	2	T-Shaped		~90°	Polar
			2	3	Linear		180°	Polar/Non-polar
6	Octahedral		6	0	Octahedral		90° sp^3d^2	Polar/Non-polar
			5	1	Square Pyramid		~90°	Polar
			4	2	Square Planar		90°	Polar/Non-polar
			3	3	T-Shaped		~90°	Polar

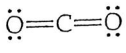
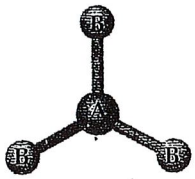
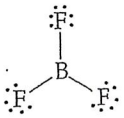
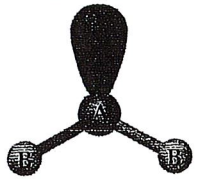
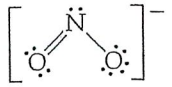
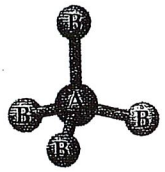
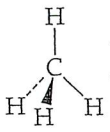
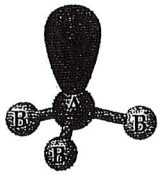
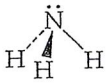
8

A	B	C	D	E	F	G	H	I
Central Atom *electron Pairs*	Electron Pair *Arrangement*	Draw Image	# of Bonding e pairs	# of lone pairs (non-bonding)	Molecular geometry	Draw Image	Bond Angels/ Hybridizatioon	Polarity
2			2	0				
3			3	0				
			2	1				
4			4	0				
			3	1				
			2	2				
5			5	0				
			4	1				
			3	2				
			2	3				
6			6	0				
			5	1				
			4	2				
			3	3				

(3)

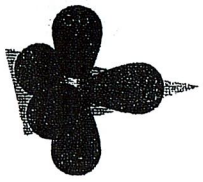
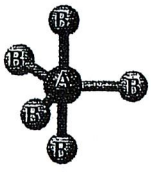
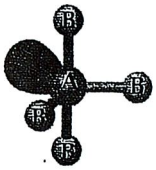
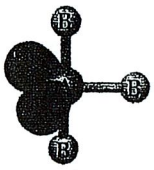
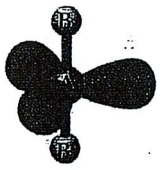
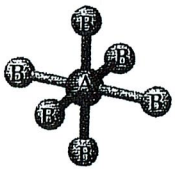
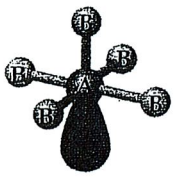
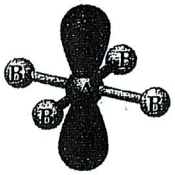
Table 9.2 ▼ summarizes the possible molecular geometries when an AB_n molecule has four or fewer electron domains about A. These geometries are important because they include all of the commonly occurring shapes found for molecules or ions that obey the octet rule.

TABLE 9.2 Electron-Domain Geometries and Molecular Shapes for Molecules with Two, Three, and Four Electron Domains Around the Central Atom

Number of Electron Domains	Electron-Domain Geometry	Bonding Domains	Nonbonding Domains	Molecular Geometry	Example
2	 Linear	2	0	 Linear	
3	 Trigonal planar	3	0	 Trigonal planar	
		2	1	 Bent	
4	 Tetrahedral	4	0	 Tetrahedral	
		3	1	 Trigonal pyramidal	
		2	2	 Bent	

(4)

TABLE 9.3 Electron-Domain Geometries and Molecular Shapes for Molecules with Five and Six Electron Domains Around the Central Atom

Total Electron Domains	Electron-Domain Geometry	Bonding Domains	Nonbonding Domains	Molecular Geometry	Example
5	 Trigonal bipyramidal	5	0	 Trigonal bipyramidal	PCl_5
		4	1	 Seesaw	SF_4
		3	2	 T-shaped	ClF_3
		2	3	 Linear	XeF_2
6	 Octahedral	6	0	 Octahedral	SF_6
		5	1	 Square pyramidal	BrF_5
		4	2	 Square planar	XeF_4

VSEPR Table AP Exam

Formulas, Geometries, Bond Angles and Example Species for AX_2 - AX_6

Formula	Location of e^- pairs	Bond Angles	Example
AX_2	linear	180°	BeH_2
AX_3	triangular	120°	BH_3
AX_4	tetrahedral	109.5°	CH_4
AX_5	trigonal bipyramidal	90° 120°	PCl_5
AX_6	octahedral	90°	SF_6

Characteristics of Species Containing Both Bonding and Nonbonding Electron Pairs

Formula	Ideal Geometry	Bonding Pairs	Nonbonding pairs	Molecular Geometry	Bond Angle*	Example
AX_3E	trigonal planar	2	1	bent	120°	O_3
AX_3E	tetrahedral	3	1	trigonal pyramidal	<109.5°	NH_3
AX_2E_2	tetrahedral	2	2	bent	<109.5°	H_2O
AX_4E	trigonal bypyramid	4	1	see-saw	<90° <120°	SF_4
AX_3E_2	trigonal bypyramid	3	2	T-shaped	90°	ClF_3
AX_2E_3	trigonal bypyramid	2	3	linear	180°	I_3^-
AX_5E	octahedral	5	1	square pyramid	90°	ICl_5
AX_4E_2	octahedral	4	2	square planar	90°	XeF_4

[* Nonbonding electrons reduce bond angle(s) from the ideal values, but the exact angles depend on the identity of the central and surrounding atoms. For example, the H-N-H angle in NH_3 is 107.5°, but the F-N-F angle in NF_3 is even smaller because the electronegative F atoms pull the bonding electrons further from the nitrogen. Similarly, the H-P-H angle in PH_3 is less than the H-N-H angle because the bonding electrons between the P and H are farther from the P (because it is larger and less electronegative).]

Summary of Electron Geometries, Molecular Geometries and Molecular Polarities

Electron regions	Electron region geometry	Bonding regions	Nonbonding regions	Molecular geometry	Polarity	Example
2	Linear	2	0	Linear	No	CO_2
3	Trigonal planar	3	0	Trigonal planar	No	BH_3
		2	1	Bent	Yes	SO_2
4	Tetrahedral	4	0	Tetrahedral	No	CH_4
		3	1	Trigonal pyramidal	Yes	NH_3
		2	2	Bent	Yes	H_2O
5	Trigonal bipyramidal	5	0	Trigonal bipyramidal	No	PCl_5
		4	1	Seesaw	Yes	SCl_4
		3	2	T-shaped	Yes	ICl_3
		2	3	Linear	No	$XeCl_2$
6	Octahedral	6	0	Octahedral	No	SCl_6
		5	1	Square pyramidal	Yes	ICl_5
		4	2	Square planar	No	$XeCl_4$

Molecular Shape

1. Draw the Lewis Structure
2. Determine the electron pair arrangement
3. Determine the molecular geometry
4. Determine the approximate bond angles
5. Determine if lone pairs distorted the shape / Hybridization
6. Determine if the molecule is polar

Name:
Class:
Date:

Lewis Structure	Elec. Pair Arrangement	Molecular Geometry	Bond Angles / Hyb	Distorted (Y/N)	Polar (Y/N)
PF_5					
SF_4					
BrF_3					

∞

Lewis Structure	Elec. Pair Arrangement	Molecular Geometry	Bond Angles ~~Hyb~~	Distorted (Y/N)	Polar (Y/N)
SF_6					
BrF_5					
XeF_4					
IO_4^-					
~~$IClO_4^+$~~ ICl_4^+					
CH_3^+					
CH_3^-					

Name: _____ Date: _____

Molecular Geometry Modeling Activity

Model	# Bonding Pairs	# Non-bonding Pairs	Total # Pairs	Electron Pair Geometry	Bond Angle(s)	Polarity NP/P	Hybridization	Sketch
A								
B								
C								
D								
E								

01

Model	# Bonding Pairs	# Non-bonding Pairs	Total # Pairs	Electron Pair Geometry	Bond Angle(s)	Polarity NP/P	Hybridization	Sketch
F								
G								
H								
I								
J								
K								

Chemical Bonding Sample AP Questions

1.

1982 D

(a) Draw the Lewis electron-dot structures for CO_3^{2-}, CO^2 and CO, including resonance structures where appropriate.

(b) Which of the three species has the shortest C-O bond length? Explain the reason for your answer.

(c) Account for the fact that the carbon-oxygen bond length in CO_3^{2-} is greater than the carbon-oxygen bond length in CO^2.

2.

1989 D

CF_4 XeF_4 ClF_3

(a) Draw a Lewis electron-dot structure for each of the molecules above and identify the shape of each.

3.

1990 D

Use simple structure and bonding models to account for each of the following:

(a) The bond length between the two carbon atoms is shorter in C_2H_4 than in C_2H_6.

(b) All the bond lengths in SO_3 are identical and are shorter than a sulfur-oxygen single bond.

4.

1992 D

NO_2 NO_2^- NO_2^+

Nitrogen is the central atom in each of the species given above.

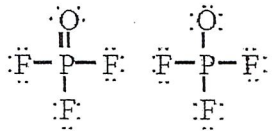
(a) Draw the Lewis electron-dot structure for each of the three species.

5.

2005 D

(c) Two Lewis structures can be drawn for the OPF_3 molecule, as shown below.

Structure 1 Structure 2



(i) How many sigma bonds and how many pi bonds are in Structure 1?

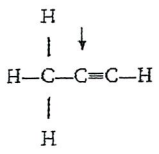
(ii) Which one of the two structures best represents a molecule of OPF_3? Justify your answer in terms of formal charge.

Hybridization Sample AP Questions

1.

2003

8(d) Given the structural formula for propyne below,



(i) Indicate the hybridization of the carbon atom indicated by the arrow in the structure above.

(ii) Indicate the total number of sigma (σ) bonds and the total number of pi (π) bonds in the molecule.

2004

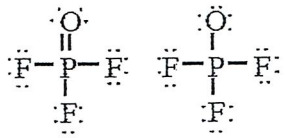
7. Use appropriate chemical principles to account for each of the following observations. In each part, your response must include specific information about both substances.
(c) The shape of the ICl_4^- ion is square planar, whereas the shape of the BF_4^- ion is tetrahedral.

2005

6(b)(ii) What is the hybridization of the valence orbitals of P in PF_5?

(c) Two Lewis structures can be drawn for the OPF_3 molecule, as shown below.

Structure 1 Structure 2



(i) How many sigma bonds and how many pi bonds are in Structure 1?

2006

7(a)(ii) Identify the hybridization exhibited by the sulfur in the SF_3^+ cation.

7(b)(ii) Identify the type of hybridization exhibited by the sulfur atom in the SF_5^- anion.

2006 Form B

6(b)(iii) What is the hybridization of the I atom in ICl_4^-?

Polarity Sample AP Questions

Indicate the type of bond expected to form between the two indicated atoms. If it is polar covalent, place a "δ-" to indicate the negative end of any dipole formed.

(a) H - H
(b) H - O
(c) H - N
(d) H - C
(e) H - F
(f) Na - Cl
(g) Cl - F

Draw a Lewis structure for each species and indicate if it is polar by placing "δ-" at the negative end of any dipole formed.

(a) carbon tetrachloride, CCl_4
(b) iodine trichloride, ICl_3
(c) hydrocyanic acid, HCN
(d) iodine pentafluoride, IF_5

Draw a Lewis structure for each species, including all resonance structures. If the spec is polar, indicate by placing "δ-" at the negative end of the dipole.

(a) sulfur dioxide, SO_2
(b) dinitrogen monoxide, N_2O
(c) nitrogen dioxide, NO_2
(d) carbon oxysulfide, SCO

Draw a Lewis structure for each species. Use the VSEPR theory to determine the electron pair geometry, then use that answer to determine the molecular geometry. Predict whether each species is polar or nonpolar.

(a) CCl_4
(b) H_2Se
(c) ClF_3
(d) XeO_3
(e) RnF_2
(f) BeH_2

Sample VSEPR AP Questions

1.

2004 Question 7

Use appropriate chemical principles to account for each of the following observations. In each part, your response *must* include specific information about *both* substances.

(c) The shape of the ICl_4^- ion is square planar, whereas the shape of the BF_4^- ion is tetrahedral.

2.

2005 Question 6

Answer the following questions that relate to chemical bonding.

(a) In the boxes provided, draw the complete Lewis structure (electron-dot diagram) for each of the three molecules represented below.

CF_4 PF_5 SF_4

(b) On the basis of the Lewis structures drawn above, answer the following questions about the particular molecule indicated.

(i) What is the F-C-F bond angle in CF_4?

(iii) What is the geometric shape formed by the atoms in SF_4?

2006 Question 7

Answer the following questions about the structures that contain only sulfur and fluorine.

(a) The compounds SF_4 and BF_3 react to form an ionic compound according to the following equation: $SF_4 + BF_3 \rightarrow SF_3BF_4$

(i) Draw a complete Lewis structure for the SF_3^+ cation in SF_3BF_4.

(iii) Identify the geometry of the SF_3^+ cation that is consistent with the Lewis structure drawn in part (a)(i).

(iv) Predict whether the F-S-F bond angle in the SF_3^+ cation is larger than, equal to, or smaller than 109.5°. Justify your answer.

(b) The compounds SF_4 and CsF react to form an ionic compound according to the following equation: $SF_4 + CsF \rightarrow CsSF_5$

(i) Draw a complete Lewis structure for the SF_5^- anion in $CsSF_5$.

(iii) Identify the geometry of the SF_5^- anion that is consistent with the Lewis structure drawn in part (b)(i).

4.

2007 Question 6

Answer the following questions that pertain to binary compounds.

(a) In the box provided, draw a complete Lewis electron-dot diagram for the IF_3 molecule.

(b) On the basis of the Lewis electron-dot diagram that you drew in part (a), predict the molecular geometry of the IF_3 molecule.

Molecular Shape

1. Draw the Lewis Structure
2. Determine the electron pair arrangement
3. Determine the molecular geometry
4. Determine the approximate bond angles
5. Determine if lone pairs distorted the shape + hybridization
6. Determine if the molecule is polar

Name:
Class:
Date:

Lewis Structure	Elec. Pair Arrangement	Molecular Geometry	Bond Angles / Hyb	Distorted (Y/N)	Polar (Y/N)
PF_5					
SF_4					
BrF_3					

5

Lewis Structure	Elec. Pair Arrangement	Molecular Geometry	Bond Angles / Hyb	Distorted (Y/N)	Polar (Y/N)
SF_6					
BrF_5					
XeF_4					
IO_4^-					
~~$IClF_4$~~ ICl_4^+					
CH_3^+					
SH_3^-					

Polarity Worksheet

For each of the following pairs of molecules, determine which is most polar and explain your reason for making this choice:

1)	carbon disulfide	OR	sulfur difluoride
2)	nitrogen trichloride	OR	oxygen dichloride
3)	boron trihydride	OR	ammonia
4)	chlorine	OR	phosphorus trichloride
5)	silicon dioxide	OR	carbon dioxide
6)	methane	OR	CH_2Cl_2
7)	silicon tetrabromide	OR	HCN
8)	nitrogen trifluoride	OR	phosphorus trifluoride

Polarity Worksheet Answers

For each of the following pairs of molecules, determine which is most polar and explain your reason for making this choice:

1) carbon disulfide OR **sulfur difluoride**
carbon disulfide is nonpolar

2) nitrogen trichloride OR **oxygen dichloride**
both are polar, but oxygen dichloride is less symmetric than nitrogen trichloride, making it more polar.

3) **boron trihydride** OR ammonia
boron trihydride is nonpolar.

4) chlorine OR **phosphorus trichloride**
chlorine is nonpolar

5) silicon dioxide OR carbon dioxide
It's a tie, because both are nonpolar

6) methane OR **CH_2Cl_2**
methane is nonpolar

7) silicon tetrabromide OR **HCN**
silicon tetrabromide is nonpolar

8) nitrogen trifluoride OR **phosphorus trifluoride**
Both are polar and equally symmetric, but the difference in electronegativity between N-F is less than that between P-F

Chemical Bonding Sample AP Questions

1.

1982 D

(a) Draw the Lewis electron-dot structures for CO_3^{2-}, CO_2 and CO, including resonance structures where appropriate.

(b) Which of the three species has the shortest C-O bond length? Explain the reason for your answer.

(c) Account for the fact that the carbon-oxygen bond length in CO_3^{2-} is greater than the carbon-oxygen bond length in CO_2.

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(a) Draw a Lewis electron-dot structure for each of the molecules above and identify the shape of each.

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Use simple structure and bonding models to account for each of the following:

(a) The bond length between the two carbon atoms is shorter in C_2H_4 than in C_2H_6.

(b) All the bond lengths in SO_3 are identical and are shorter than a sulfur-oxygen single bond.

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1992 D

NO_2 NO_2^- NO_2^+

Nitrogen is the central atom in each of the species given above.

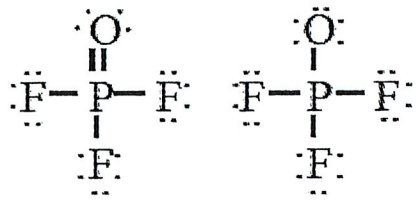
(a) Draw the Lewis electron-dot structure for each of the three species.

5.

2005 D

(c) Two Lewis structures can be drawn for the OPF_3 molecule, as shown below.

Structure 1 Structure 2



(i) How many sigma bonds and how many pi bonds are in Structure 1?

(ii) Which one of the two structures best represents a molecule of OPF_3? Justify your answer in terms of formal charge.

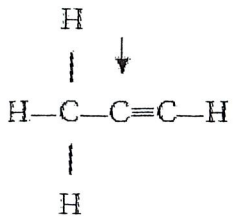
20

Hybridization Sample AP Questions

1.

2003

8(d) Given the structural formula for propyne below,



(i) Indicate the hybridization of the carbon atom indicated by the arrow in the structure above.

(ii) Indicate the total number of sigma (σ) bonds and the total number of pi (π) bonds in the molecule.

2004

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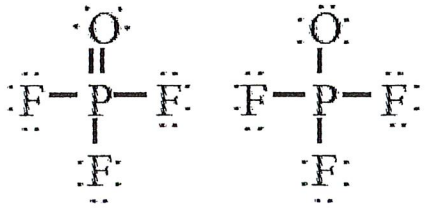
Structure 1 Structure 2



(i) How many sigma bonds and how many pi bonds are in Structure 1?

2006

7(a)(ii) Identify the hybridization exhibited by the sulfur in the SF_3^+ cation.

7(b)(ii) Identify the type of hybridization exhibited by the sulfur atom in the SF_5^- anion.

2006 Form B

6(b)(iii) What is the hybridization of the I atom in ICl_4^-?

Polarity Sample AP Questions

(A) Indicate the type of bond expected to form between the two indicated atoms. If it is polar covalent, place a "δ-" to indicate the negative end of any dipole formed.

(a) H - H
(b) H - O
(c) H - N
(d) H - C
(e) H - F
(f) Na - Cl
(g) Cl - F

(B) Draw a Lewis structure for each species and indicate if it is polar by placing "δ-" at the negative end of any dipole formed.

(a) carbon tetrachloride, CCl_4
(b) iodine trichloride, ICl_3
(c) hydrocyanic acid, HCN
(d) iodine pentafluoride, IF_5

(C) Draw a Lewis structure for each species, including all resonance structures. If the spe is polar, indicate by placing "δ-" at the negative end of the dipole.

(a) sulfur dioxide, SO_2
(b) dinitrogen monoxide, N_2O
(c) nitrogen dioxide, NO_2
(d) carbon oxysulfide, SCO

(D) Draw a Lewis structure for each species. Use the VSEPR theory to determine the electron pair geometry, then use that answer to determine the molecular geometry. Predict whether each species is polar or nonpolar.

(a) CCl_4
(b) H_2Se
(c) ClF_3
(d) XeO_3
(e) RnF_2
(f) BeH_2

Sample VSEPR AP Questions

1.

2004 Question 7

Use appropriate chemical principles to account for each of the following observations. In each part, your response *must* include specific information about *both* substances.

(c) The shape of the ICl_4^- ion is square planar, whereas the shape of the BF_4^- ion is tetrahedral.

2.

2005 Question 6

Answer the following questions that relate to chemical bonding.

(a) In the boxes provided, draw the complete Lewis structure (electron-dot diagram) for each of the three molecules represented below.

CF_4 PF_5 SF_4

(b) On the basis of the Lewis structures drawn above, answer the following questions about the particular molecule indicated.

(i) What is the F-C-F bond angle in CF_4?

(iii) What is the geometric shape formed by the atoms in SF_4?

2006 Question 7

Answer the following questions about the structures that contain only sulfur and fluorine.

(a) The compounds SF_4 and BF_3 react to form an ionic compound according to the following equation: $SF_4 + BF_3 \rightarrow SF_3BF_4$

(i) Draw a complete Lewis structure for the SF_3^+ cation in SF_3BF_4.

(iii) Identify the geometry of the SF_3^+ cation that is consistent with the Lewis structure drawn in part (a)(i).

(iv) Predict whether the F-S-F bond angle in the SF_3^+ cation is larger than, equal to, or smaller than 109.5°. Justify your answer.

(b) The compounds SF_4 and CsF react to form an ionic compound according to the following equation: $SF_4 + CsF \rightarrow CsSF_5$

(i) Draw a complete Lewis structure for the SF_5^- anion in $CsSF_5$.

(iii) Identify the geometry of the SF_5^- anion that is consistent with the Lewis structure drawn in part (b)(i).

4.

2007 Question 6

Answer the following questions that pertain to binary compounds.

(a) In the box provided, draw a complete Lewis electron-dot diagram for the IF_3 molecule.

(b) On the basis of the Lewis electron-dot diagram that you drew in part (a), predict the molecular geometry of the IF_3 molecule.

Name:_____ Class:_____

Chapter 8 Review

This is a general review for the material covered in this chapter. It is intended to be a supplementary study tool that should be used in conjunction with all notes, worksheets, and your text. Please show all work and circle your final answer for full credit.

1. *Complete the chart below*

	Ionic Bonds	***Covalent Bonds***	***Metallic Bonds***
Definition			
Example			
Three Characteristics			
Electronegativity		***Polar:*** ***Non Polar:***	***NA***
Illustrate Sharing	***Ionic:***	***Polar:***	***Non Polar:***

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2. For each of the following pairs of molecules, determine which is most polar and explain your reason for making this choice.

carbon disulfide OR *sulfur difluoride*

nitrogen trichloride OR *oxygen dichloride*

boron trihydride OR *ammonia*

3. Draw the Lewis Structures for the following molecules

A. HBr

C. N_2F_4

D. SF_6

B. C_2H_5OH (ethanol)

4. Draw all of the possible resonance structures for the following ions or molecules:

A. sulfur dioxide:

C. cyclobutadiene (C_4H_4):

B. formate ion (CHO_2^{-1}):

D. ozone (O_3):

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5. A. What does VSEPR stand for?
   B. What is the main idea behind VSEPR theory? Explain.

6. For each of the following compounds, determine the bond angles, molecular shapes, polarity, hybridization and Lewis structure:

A. carbon tetrachloride

B. BH_3

C. silicon disulfide

D. C_2H_2

E. PF_3

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7. A. Define isoelectric ions
   B. Give an example that supports your definition
   C. Which ion in your example has a larger atomic radius **and** why

8. Define Bond Enthalpy

9. Calculate the formal charge for each atom for the molecules in question 3 listed below.

A. C_2H_5OH *(ethanol)*

C. N_2F_4

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