PERIODICITY DATA ANALYSIS: TRENDS AND DISCONTINUITIES

Purpose:

- Determine Periodic Trends
- Explain Discontinuities using knowledge of atomic structure and interactions

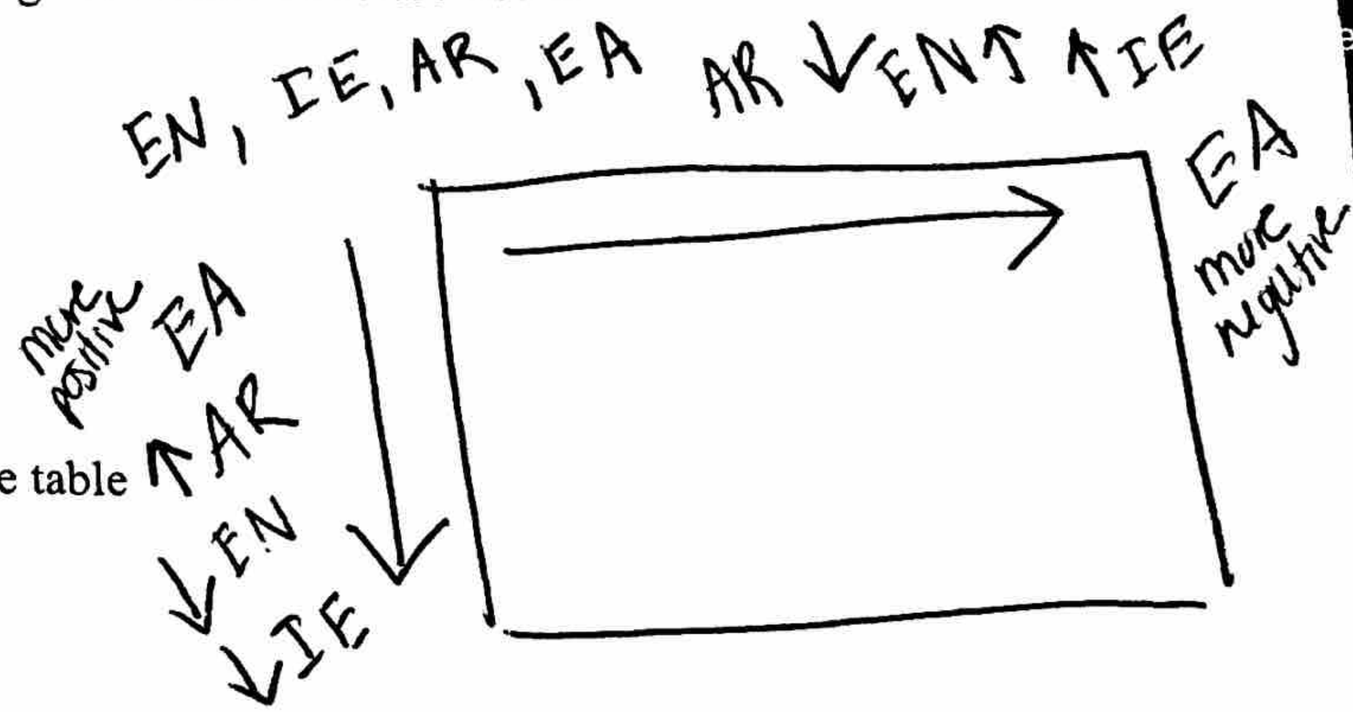
Definitions:

Period: a horizontal row of the table
What does the period number tell you?

the number of energy levels

Group / Family: a vertical column of the table
What does the group number tell you?

the number of valence electrons



Periodic law: properties repeat (happen *periodically*) if you arrange elements in order of increasing atomic number (Z)

Before you begin, define the following terms:

Atomic radius – half the distance between the nuclei in a molecule of two identical atoms

Ionization Energy – the energy required to remove an electron from an atom or ion

Electron Affinity – the energy change associated with the addition of an electron to an atom

Electronegativity – the ability to attract an electron

Effective nuclear charge – the positive charge that is experienced by an electron

Isoelectronic – ions containing the same # of electrons

Cl^- + K^+

1.

AP Chemistry

Name _____

Period ___ Date __/__/__

9 • Bonding & Molecular Structure

ELECTRONEGATIVITY

1 H 2.1												5 B 2.0	6 C 2.5	7 N 3.0	8 O 3.5	9 F 4.0
3 Li 1.0	4 Be 1.5											13 Al 1.5	14 Si 1.8	15 P 2.1	16 S 2.5	17 Cl 3.0
11 Na 1.0	12 Mg 1.2											31 Ga 1.7	32 Ge 1.9	33 As 2.1	34 Se 2.4	35 Br 2.8
19 K 0.9	20 Ca 1.0	21 Sc 1.3	22 Ti 1.4	23 V 1.5	24 Cr 1.6	25 Mn 1.6	26 Fe 1.7	27 Co 1.7	28 Ni 1.8	29 Cu 1.8	30 Zn 1.6	49 In 1.6	50 Sn 1.8	51 Sb 1.9	52 Te 2.1	53 I 2.5
37 Rb 0.9	38 Sr 1.0	39 Y 1.2	40 Zr 1.3	41 Nb 1.5	42 Mo 1.6	43 Tc 1.7	44 Ru 1.8	45 Rh 1.8	46 Pd 1.8	47 Ag 1.6	48 Cd 1.6	81 Tl 1.6	82 Pb 1.7	83 Bi 1.8	84 Po 1.9	85 At 2.1
55 Cs 0.8	56 Ba 1.0	57 La 1.1	72 Hf 1.3	73 Ta 1.4	74 W 1.5	75 Re 1.7	76 Os 1.9	77 Ir 1.9	78 Pt 1.8	79 Au 1.9	80 Hg 1.7					
87 Fr 0.8	88 Ra 1.0	89 Ac 1.1														

1. In each pair of bonds, put a star (★) next to the more polar bond and use an arrow (+⟶) to show the direction of polarity in each bond.

a) ★ +⟶ C—O (1.0) and C—N

b) P—Br (.7) and ★ +⟶ P—Cl (.9)

c) ★ +⟶ B—O and B—S (1.5)

d) ★ +⟶ B—F (2.0) and B—I (.5)

2. For each of the bonds listed below, indicate (+⟶) which atom is the more negatively charged.

a) +⟶ C—N

b) ⟵ C—H

c) +⟶ C—Br

d) +⟶ S—O

It is somewhat artificial to classify bonds based on the differences in the electronegativities (Δ_x) of the two atoms. However, we will use these ranges to do so:

Ionic	$\Delta_x > 1.7$	(symbolized as A^+ and Z^-)
Polar Covalent	$1.7 \geq \Delta_x \geq .5$	(symbolized as $A^{\delta+}$ and $Z^{\delta-}$)
Pure Covalent	$\Delta_x < .5$	(no charges)

3. For each of the bonds listed below, classify each bond and indicate full or partial charges, if any.

a) $Na^+—Cl^-$ ionic 3-1=2

b) $C^{\delta+}—O^{\delta-}$ polar covalent 3.5-2.5=1.0

c) $Cu^{\delta+}—O^{\delta-}$ polar covalent 3.5 - 1.8 = 1.7

d) C—H covalent 2.5-2.1 = .3

e) $Mg^{\delta+}—H^{\delta-}$ polar covalent 2.1 - 1.2 = .9

f) $Cs^+—F^-$ ionic 4.0 - .8 = 3.2

g) Cl—Cl covalent 3.0 - 3.0 = 0.0

h) $Al^{\delta+}—Cl^{\delta-}$ polar covalent 3.0 - 1.5 = 1.5

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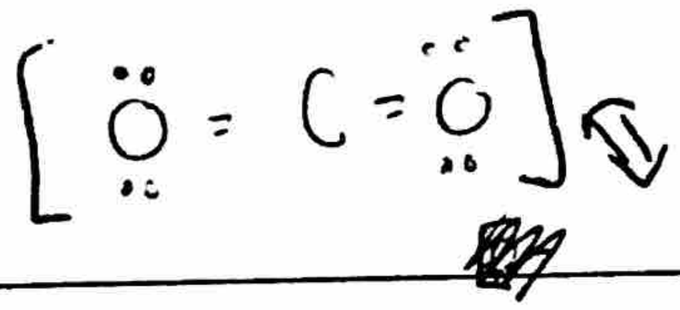
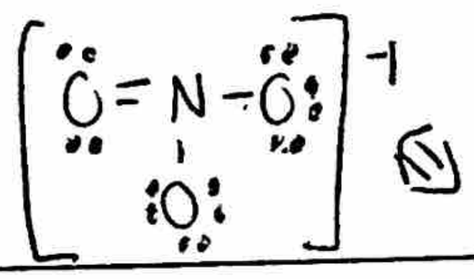
9 • Bonding & Molecular Structure

LEWIS STRUCTURE PRACTIC

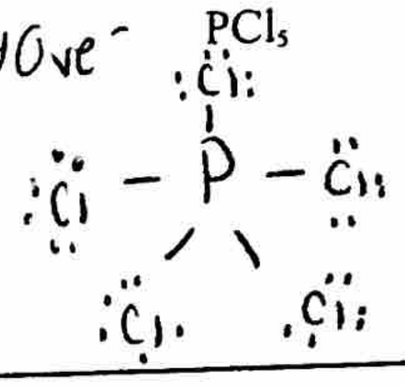
ve = 16 CO_2



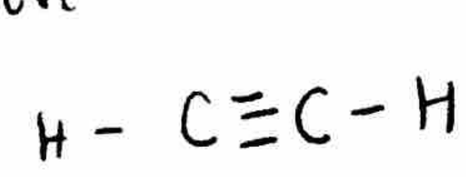
ve = 24 NO_3^-



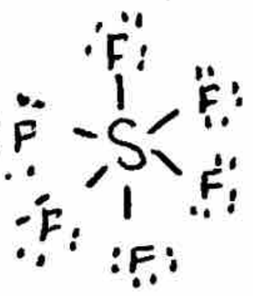
ve = 40 ve⁻ PCl_5



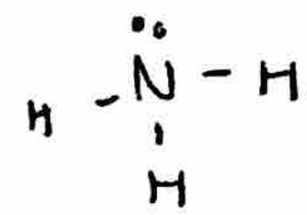
ve = 10 ve⁻ C_2H_2



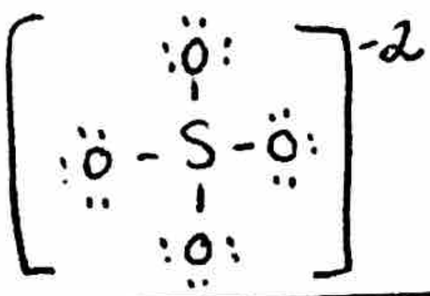
ve = 48 ve⁻ SF_6



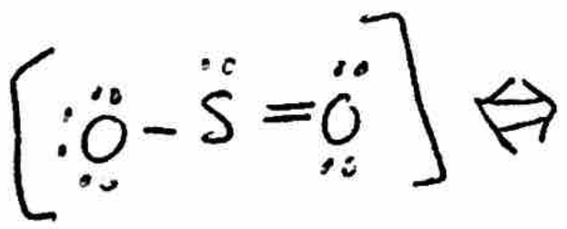
ve = 8 ve⁻ NH_3



ve = 32 ve⁻ SO_4^{2-}

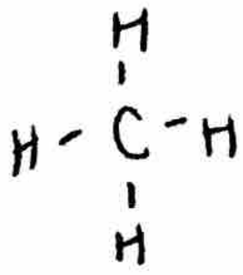


ve = 18 SO_2

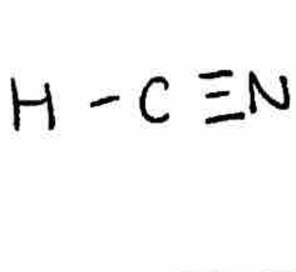


ve = 8 H_2S

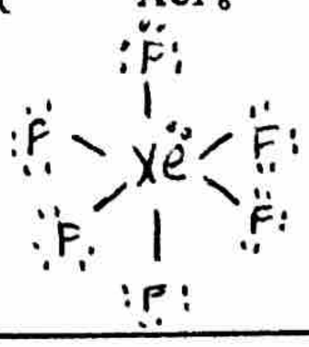
ve = 8 ve⁻ CH_4



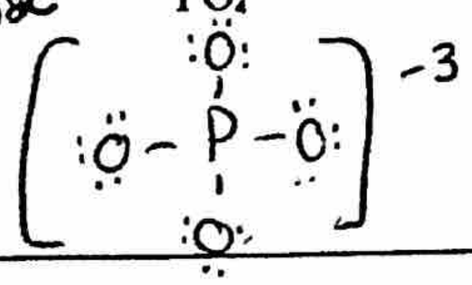
ve = 10 HCN



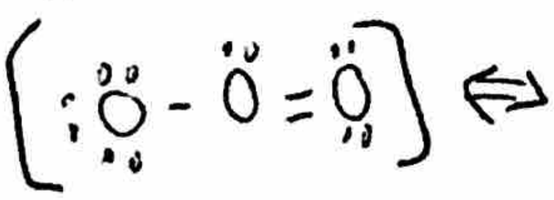
ve = 50 ve⁻ XeF_6



ve = 32 PO_4^{3-}

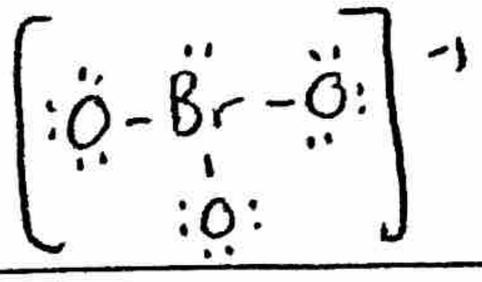


ve = 18 O_3

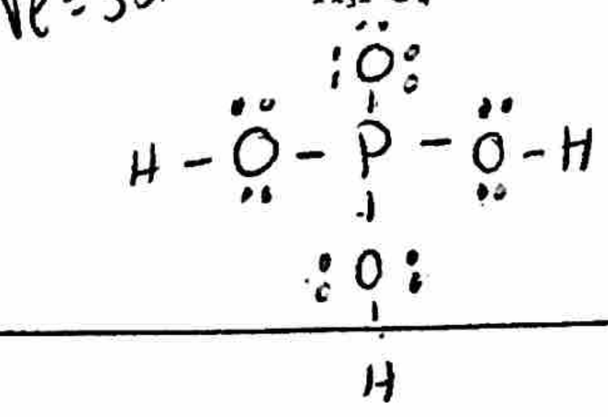


ve = 34 SF_4

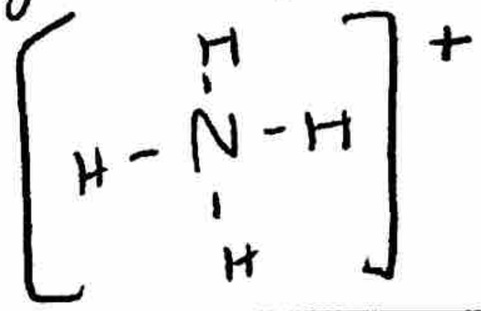
ve = 26 BrO_3^{-1}

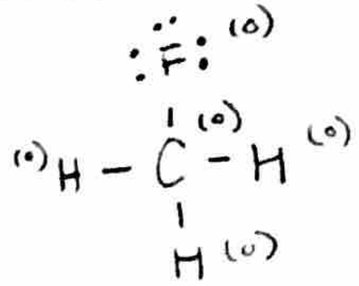
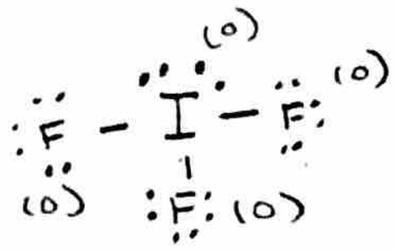
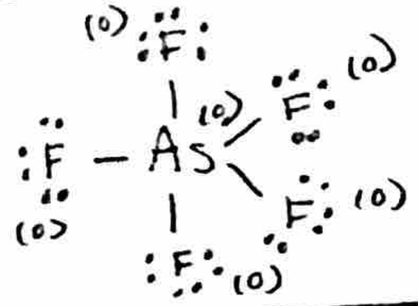
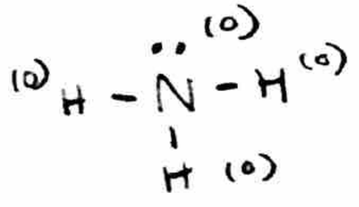
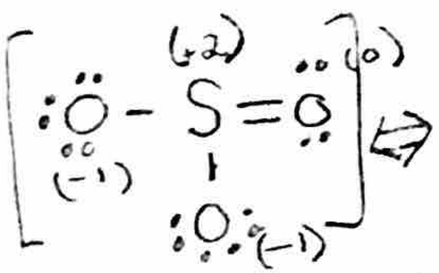
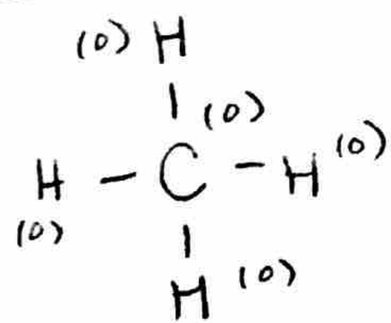


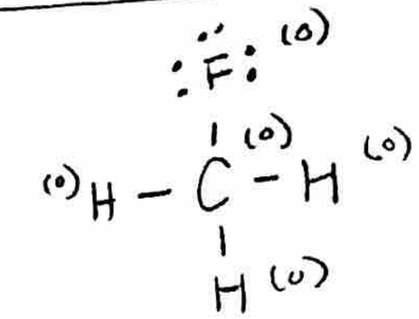
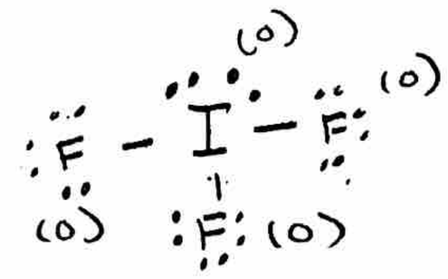
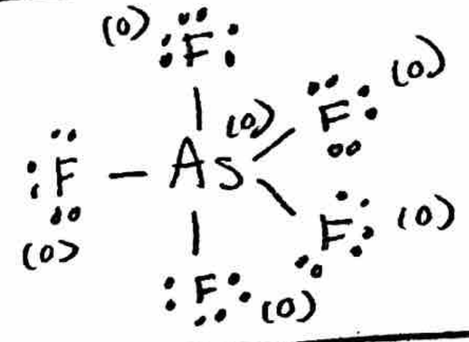
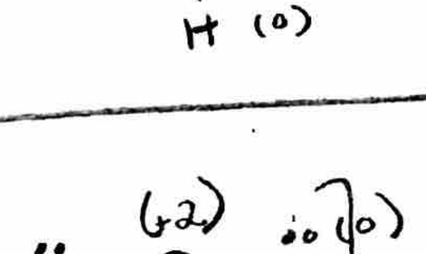
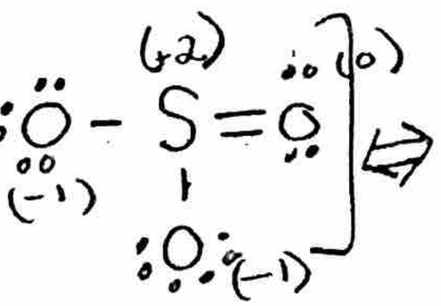
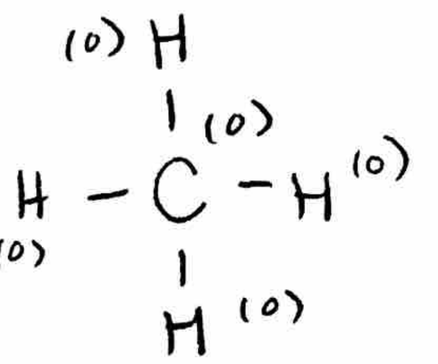
ve = 32 H_3PO_4

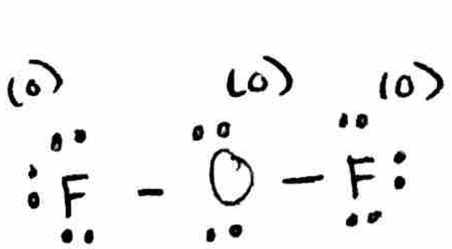
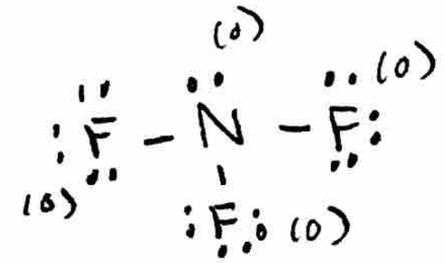
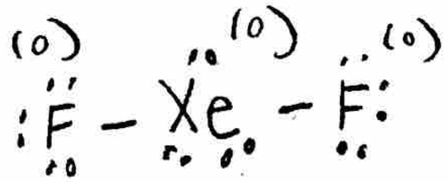
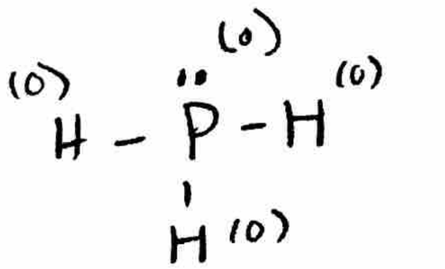
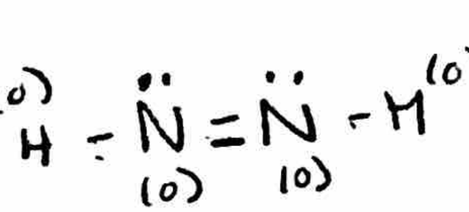
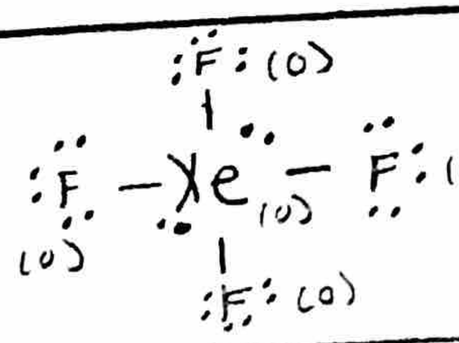


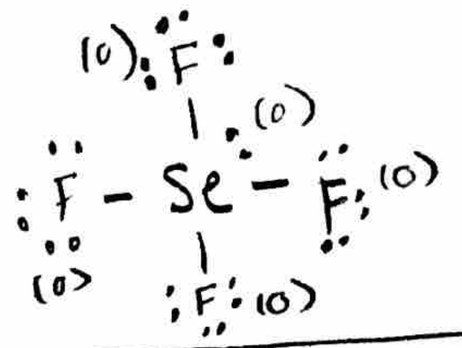
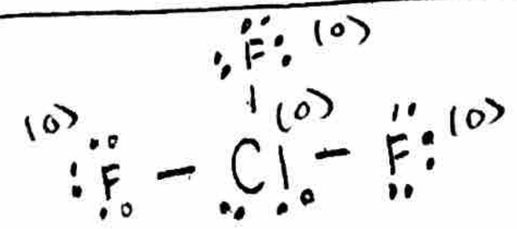
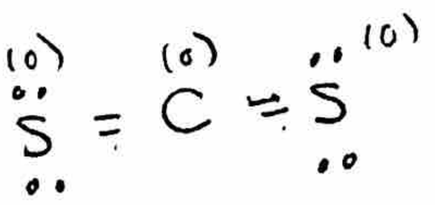
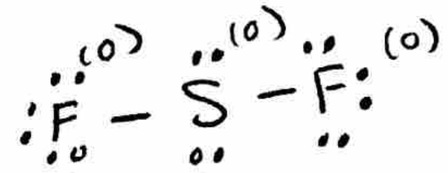
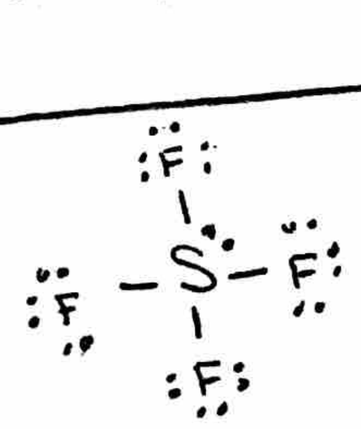
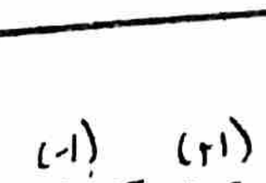
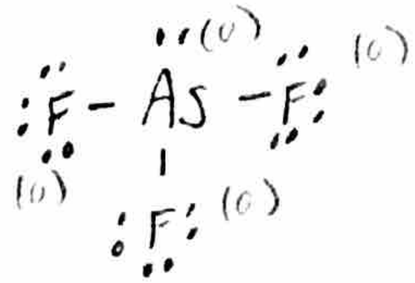
ve = 8 NH_4^+

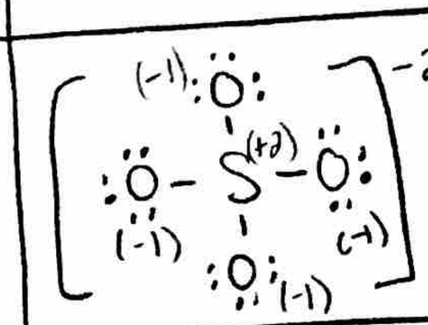
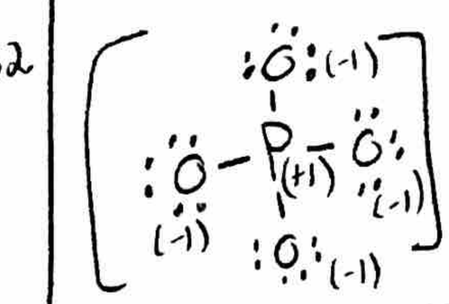
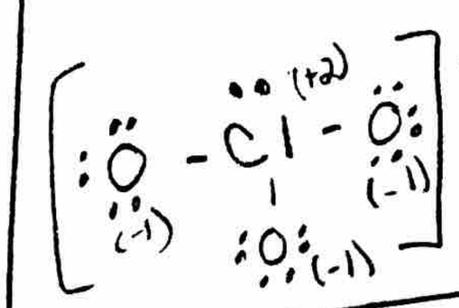
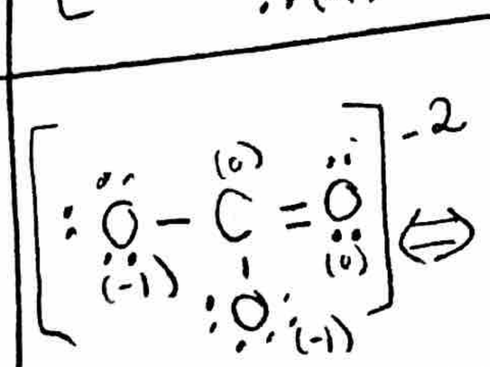
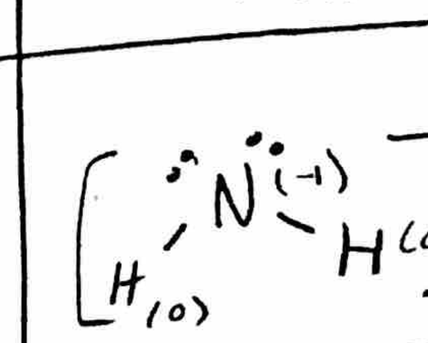
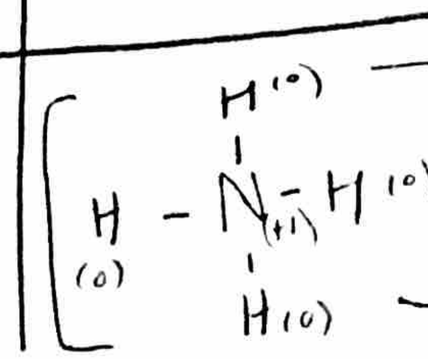


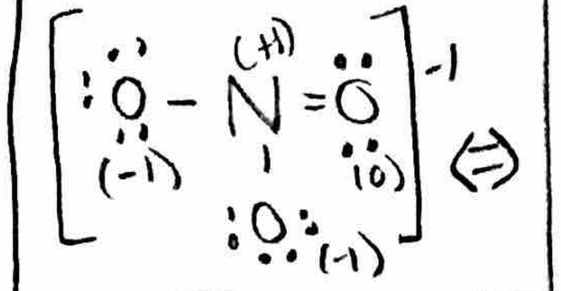
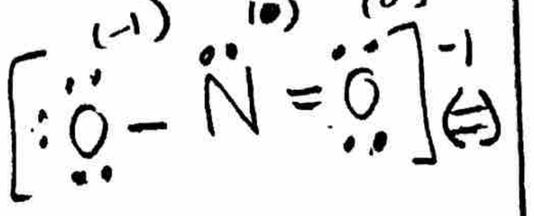
olecule	Lewis structure	Steric Number	Molecular Shape	Hybridization	
ve=14 $_3F$		4	tetiahedral	C = sp^3 H = s F = sp^3	P
ve=28 F_3		5	+-shape	I = sp^3d F = sp^3	P
ve=40 F_5		5	trigonal bipyramid	As = sp^3d F = sp^3	NP
ve=8 H_3		4	trigonal pyramid	N = sp^3 H = s	P
ve=24 O_3		3	trigonal planar	S sp^2 O= sp^2 O- sp^3	NP
ve=8 H_4		4	tetiahedral	C = sp^3 H = s	NP

Molecule	Lewis structure	Steric Number	Molecular Shape	Hybridization	P / NP
CH_3F ve = 14		4	tetrahedral	C = sp^3 H = s F = sp^3	P
IF_3 ve = 28		5	T-shape	I = sp^3d F = sp^3	P
AsF_5 ve = 40		5	trigonal bipyramid	As = sp^3d F = sp^3	NP
NH_3 ve = 8		4	trigonal pyramid	N = sp^3 H = s	P
SO_3 ve = 24		3	trigonal planar	S sp^2 O = sp^2 O − sp^3	NP
CH_4 ve = 8		4	tetrahedral	C = sp^3 H = s	NP

ve: 20 OF_2		4	bent	O = sp^3 F = sp^3	P
ve=24 NF_3		4	trigonal pyramid	N = sp3 F = sp^3	P
ve=22 XeF_2		5	linear	Xe = sp^3d F = sp^3	NP
ve=8 PH_3		4	trigonal pyramid	P = sp^3 H = s	P
ve=12 N_2H_2		4	bent	N = sp^3 H = s	P
ve=36 XeF_4		6	square planar	Xe = sp^3d^2 F = sp^3	NP
ve=48 SeF_6		6	octahedral	Se = sp^3d^2 F = sp^3	NP

SeF_4 ve=34		5	see-saw	Se = sp^3d F = sp^3	P
ClF_3 ve=28		5	t-shape	Cl - sp^3d F = sp^3	P
CS_2 ve=14		2	linear	C = sp S = sp^2	NP
SF_2 ve=20		4	bent	S = sp^3 F = sp^3	P
SF_4 ve=34		5	see-saw	S = sp^3d F = sp^3	P
CO ve=10		2	linear	C = sp O = sp	P
AsF_3 ve=26		4	trigonal pyramid	As = sp^3 F = sp^3	P

CN^- ve=10		2	linear	C = sp N = sp	P
SO_4^{-2} ve=32		4	tetrahedral	S = sp^3 O = sp^3	NP
PO_4^{-3} ve=32		4	tetrahedral	P = sp^3 O = sp^3	NP
ClO_3^- ve=26		4	trigonal pyramid	Cl = sp^3 O = sp^3	P
CO_3^{-2} ve=24		3	trigonal planar	C = sp^2 O = sp^2 o - sp^3	NP
NH_2^- ve=8		4	bent	N = sp^3 H = S	P
NH_4^+ ve=8		4	tetrahedral	N = sp^3 H = S	NP

NO_3^- ve: 24		3	trigonal planar	N = sp^2 O = sp^2 O− sp^3	NP
NO_2^- ve: 18		3	bent	N = sp^2 O = sp^2 O− sp^3	P

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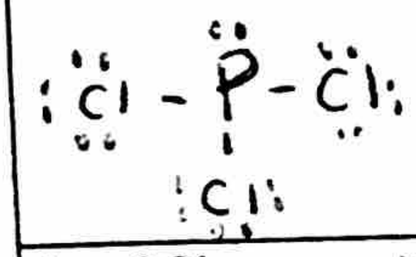
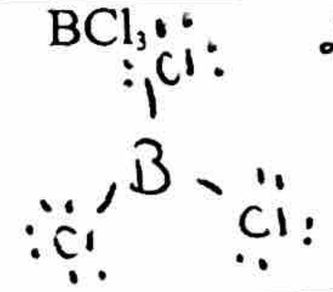
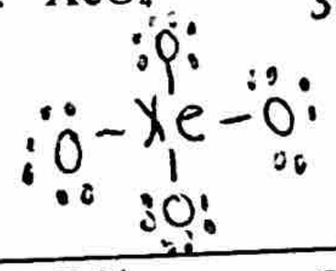
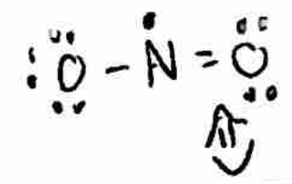
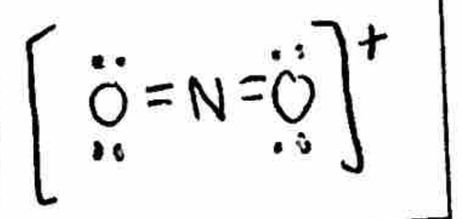
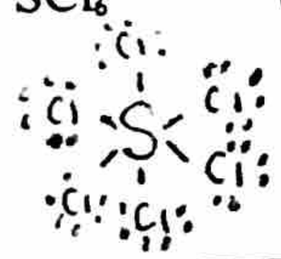
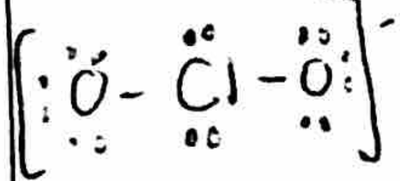
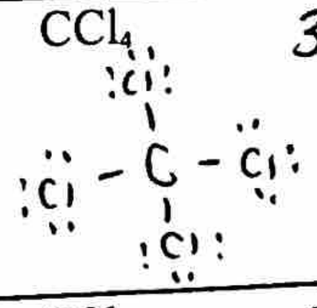
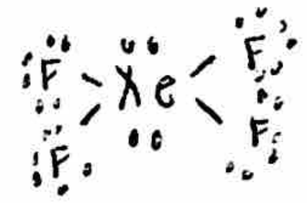
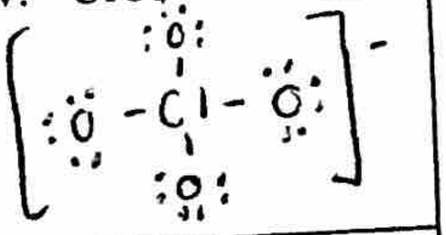
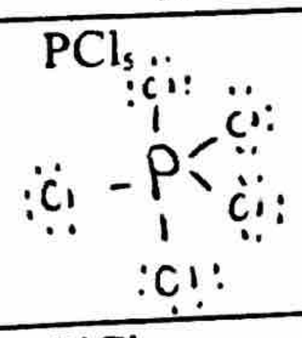
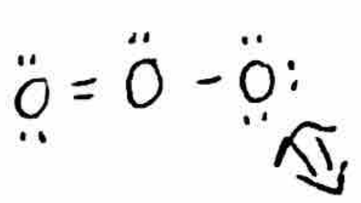
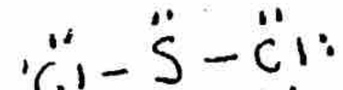
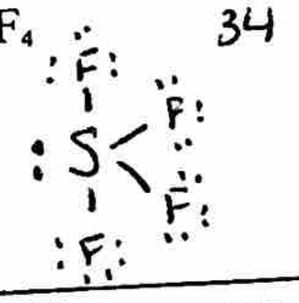
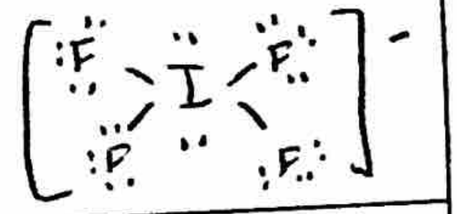
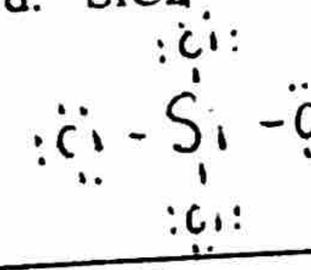
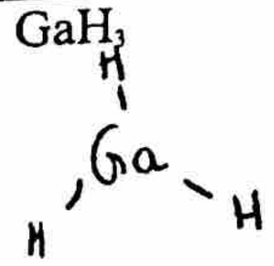
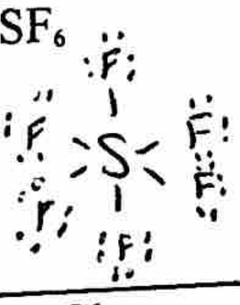
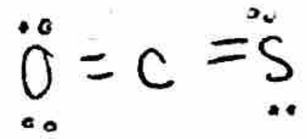
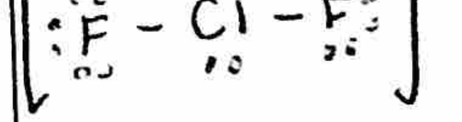
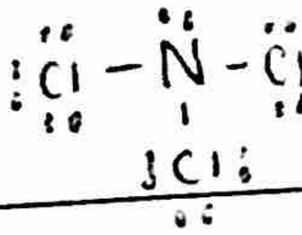
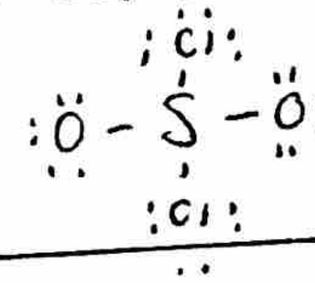
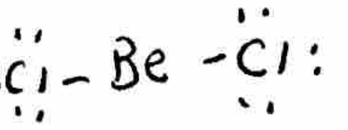
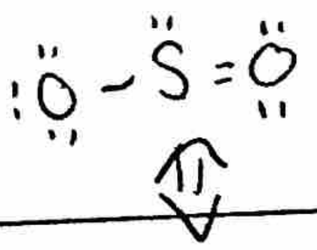
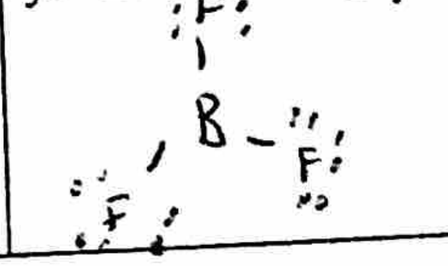
9 • Hybridization

STUDY QUESTIONS

1. What hybridization is required at the central atom of the following molecules or ions? Sketch the Lewis electron-dot diagram; state the Steric Number (SN) and then state the hybridization.

a. PCl_3 26 	f. BCl_3 24 	k. XeO_4 32 	p. NO_2 17 	u. NO_2^+ 16 
b. SCl_6 48 	g. ClO_2^- 20 	l. CCl_4 32 	q. XeF_4 36 	v. ClO_4^- 32 
c. PCl_5 40 	h. O_3 18 	m. SCl_2 20 	r. SF_4 34 	w. IF_4^- 36 
d. $SiCl_4$ 32 	i. GaH_3 6 	n. SF_6 48 	s. OCS 16 	x. ClF_2^+ 20 
e. NCl_3 26 	j. SO_2Cl_2 32 	o. $BeCl_2$ 16 	t. SO_2 18 	y. BF_3 24 

a) 4 sp^3

b) 6 sp^3d^2

c) 5 sp^3d

d) 4 sp^3

e) 4 sp^3

f) 3 sp^2

g) 4 sp^3

h) 3 sp^2

i) 3 sp^2

j) 3 sp^2

k) 4 sp^3

l) 4 sp^3

m) 4 sp^3

n) 6 sp^3d^2

o) 2 sp

p)

q) 6 sp^3d^2

r) 5 sp^3d

s) 2 sp

t) 3 sp^2

u) 2 sp

v) 4 sp^3

w) 6 sp^3d^2

x) 4 sp^3

y) 3 sp^2

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9 • Bonding & Molecular Structure

BOND ENERGIES

Table 9.9 • Some Average Single- and Multiple-Bond Energies (kJ/mol)

	H	C	N	O	F	Si	P	S	Cl	Br	I
H	**436**	**413**	**391**	**463**	**565**	**318**	**322**	**347**	**432**	**366**	**299**
C		346	305	358	485			272	339	285	213
N			**163**	**201**	**283**				**192**		
O				146		452	335		218	201	201
F					**155**	**565**	**490**	**284**	**253**	**249**	**278**
Si						222		293	381	310	234
P							**201**		**326**		**184**
S								226	255		
Cl									**242**	**216**	**208**
Br										193	175
I											**151**

Multiple Bonds

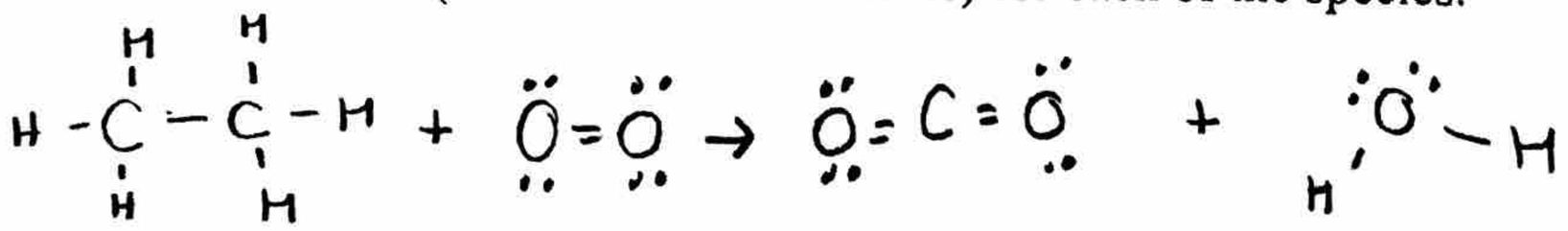
N=N	418	C=C	602
N≡N	945	C≡C	835
C=N	615	C=O	732
C≡N	887	C≡O	1072
O=O (in O_2)	498		

Table 6.2 • Standard Enthalpies of Formation (kJ/mol)		
$C_2H_6(g)$	ethane	-84.7
$H_2O(g)$	water vapor	-241.8
$CO_2(g)$	carbon dioxide	-393.5

1. Write the balanced chemical equation for the complete combustion of ethane, $C_2H_6(g)$.

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

2. Draw structural formulas (shortcut Lewis structures) for each of the species.



3. Calculate the energy needed to break the bonds in the reactants. 9134 KJ/mol
   Calculate the energy released as the bonds in the products are formed. 11412 KJ/mol

C-H 12(413)
C-C 2(346) = 9134 KJ/mol
O=O 7(498)

C=O 8(732)
O-H 18(463) = 11412 KJ/mol

4. What is the $\Delta H_{combustion}$ based on bond energies? -2278 KJ/mol

9134 - (11412) =

5. On the back of this page, calculate the $\Delta H_{combustion}$ using Hess's Law and the thermochemical data from Chapter 6.