Chem 130 – Second Exam

Name_____

On the following pages you will find eight questions covering varies topics ranging from the geometry of inorganic compounds to different types of bonding. Read each question carefully and consider how you might approach the problem before you put pen or pencil to paper. If you aren't sure how to start a question, move to another problem; working on a new question may suggest an approach to that more troublesome problem. For problems requiring a written response, be sure that your answer is written in complete sentences and that it directly and clearly answers the question.

Partial credit is willingly given on all problems so be sure to answer all questions!

Question 1 _____/28	Question 5 _____/10
Question 2 _____/6	Question 6 _____/10
Question 3 _____/16	Question 7 _____/10
Question 4 _____/4	Question 8 _____/16

Total _____/100

Potentially useful equations and constants:

$c = \lambda\nu$ $\quad E = h\nu$ $\quad KE = h\nu - BE$ $\quad \frac{1}{\lambda} = 1.09737\times10^{-2}\ \text{nm}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ $\quad V = \frac{kq_1q_2}{d}$

$$FC_a = V_a - N_a - \frac{B_a}{2} \quad \delta_a = V_a - N_a - B_a\left(\frac{EN_a}{EN_a + EN_b}\right)$$

$$OX_a = V_a - N_a - B_a \times (0 \text{ if least EN}; 1 \text{ if most EN})$$

$c = 2.998\times10^{8}$ m/s $\quad h = 6.626\times10^{-34}$ Js $\quad N_A = 6.022\times10^{23}$ mol^{-1}

Problem 1. For each of the following molecules or ions, draw any <u>one</u> valid Lewis structure of your choosing (it need not be the "best" structure). Annotate your structure by indicating the formal charge on each atom. Finally, state the name for the bonding geometry around the underlined central atom, predict whether the molecule or ion is polar or non-polar, and give the idealized bond angle for the stated bonds.

Molecule or Ion	Lewis Structure	Bonding Geometry	Polar or Non-Polar?	Ideal Bond Angle
$\underline{C}Cl_2F_2$	There are 32 electrons and four substiuents around the central atom, requiring four electron domains. The only possible LS has single bonds from C to Cl and from C to F. All formal charges are zero.	tetrahedral	Polar	Bond angle for an F-C-Cl bond is 109.5^o
$\underline{I}O_2F_2^-$	There are 34 electrons and four substiuents around the central atom, requiring five electron domains with the lone pair in an axial position. Using single bonds to O and F gives formal charges of zero for F and -1 for O and +1 for I.	see-saw	Polar	Bond angle for a O-I-O bond is 120^o
$\underline{I}Cl_4^-$	There are 36 electrons and four substiuents around the central atom, requiring six electron domains. The only possible LS has single bonds from I to Cl. All formal charges on Cl are zero, leaving a formal charge of -1 on I.	square planar	Non-polar	Bond angle for a Cl-I-Cl bond is 90^o
$\underline{Xe}OF_4$	There are 42 electrons and five substiuents around the central atom, requiring six electron domains. With a double bond between Xe and O and single bonds between Xe and F, all formal charges are zero.	square pyramidal	Polar	Bond angle for an F-Xe-F bond is 90^o

Problem 2. An element Z forms the ion ZF_2^- with a linear geometry. Give an example of an element that could be Z. Be sure to clearly explain your reasoning in one or two sentences.

A linear geometry means either two or five electron domains. Two electron requires an alkali metal, which would give an ionic compound for which a linear geometry has no meaning. Five electron domains requires three lone pairs of electrons on Z, for a total of 22 electrons for ZF_2^- and seven electrons for Z. Possible elements are Cl, Br, I and At.

Problem 3. Partial charges, formal charges and oxidation numbers describe the arrangement of electrons or charge in a molecule or ion. Provide a one sentence definition (no formulas) for each that explains what information it provides.

partial charge: The partial charge provides information about the distribution of electrons in covalent bonds by assuming that the electrons are not shared equally.

formal charge: A formal charge provides information about the distribution of electrons assuming that all bonds are purely covalent (that is, the electrons are shared equally).

oxidation number: An oxidation number provides information about the distribution of electrons by assuming that all bonds are ionic.

Consider the compound IBr. What are the formal charges, partial charges and oxidation numbers for each atom in this compound? Place your answers in the table and show your work in the space below the table.

	Br	I
formal charge	0	0
partial charge	-0.065	+0.065
oxidation number	-1	+1

The Lewis structure has a single bond between Br and I, with three lone-pairs of electrons on each. From the perspective of formal charges, each element brings 7 electrons into the structure and has 7 electrons in the structure; thus, the formal charge on each is zero. Partial charges are calculated using the formula for δ_a on the front of the exam. The oxidation numbers are found by treating the compound as if it were ionic. In this case the more electronegative species, Br, takes both of the bonding electrons, leaving it with 8 electrons and an oxidation number of -1; I, therefore, has an oxidation number of +1.

Which of these provides the most accurate information about the distribution of charge within the molecule? Defend your choice in one sentence.

For a more covalent-like molecule, partial charges provide the most accurate information about the distribution of charge because they account for the unequal pull of the two atoms on the shared electrons.

Problem 4. Barium ferrate, $BaFeO_4$, is being tested for use in batteries for hybrid cars. What is the oxidation state for iron in this compound. To receive partial credit for this problem you must explain how you arrived at your answer.

Each oxygen has an oxidation state of -2 for a total of -8 and barium has an oxidation state of +2. The oxidation state for iron, therefore, must be +6 to give a net charge of zero.

Problem 5. Consider the following molecules and ions—NO_2^-, CO_3^{2-}, BF_3 and NH_3. The central atom for three of these compounds use the same type of hybrid orbitals; the fourth compound uses a different set of hybrid orbitals. Identify the molecule or ion that is different and indicate its hybridization. Be sure to explain your reasoning.

The ions NO_3^- and CO_3^{2-}, and the molecule BF_3 have three electron domains and are trigonal planar in geometry. All three, therefore, have the same hybridization. Ammonia, NH_3, has four electron domains, requiring a tetrahedral arrangement of electron domains and sp^3 hybridization.

Problem 6. The following compounds—HCl, ICl and SCl_2—are generally considered to be covalent. As we have seen, a pure covalent bond is rare. Rank these compounds from that with the least ionic character to that with the greatest ionic character. Place your answers in the table and show any relevant work and/or explanation in the space below the table.

least ionic	←→	most ionic
SCl_2	ICl	HCl

Ionicity is given by the difference in electronegativities (ΔEN) between the two elements. The greatest ΔEN is for HCl, which is the most ionic, and the smallest ΔEN is for SCl_2, which is the least ionic.

Problem 7. The following compounds—MgH_2, $BaSi_2$ and ZnS—have similar ionic characters, but differ in the degree of metallic and covalent character. Rank these compounds from that with the most metallic character to that with the most covalent character. Place your answers in the table and show any relevant work and/or explanation in the space below the table.

most metallic	←→	most covalent
MgH_2	$BaSi_2$	ZnS

Covalency is given by the average electronegativity of the elements. The largest average electronegativity is ZnS, which is the most covalent, and the smallest average electronegativity is for MgH_2, which is the most metallic.

Problem 8. Molecular orbitals form when atomic orbitals or hybrid orbitals interact. Consider the three p-orbitals on an atom. When these orbitals interact with the three p-orbitals on another atom, what types of molecular orbitals form (name and symbol)? How many of each different type of orbital form? For each type of molecular orbital, draw a picture showing where the electron density is found. Place your answers in the table below (note – there are more rows than there are answers).

type of molecular orbital	number of molecular orbitals	sketch showing distribution of electrons in the molecular orbital (each • represents an atom)
sigma bonding	1	see Figure 4A.6 on page 167 of your text for pictures showing this molecular orbital
sigma antibonding	1	see Figure 4A.6 on page 167 of your text for pictures showing this molecular orbital
pi bonding	2	see Figure 4A.6 on page 167 of your text for pictures showing this molecular orbital
pi antibonding	2	see Figure 4A.6 on page 167 of your text for pictures showing this molecular orbital