Chem 130 – Second Exam Key

Name________________________________

On the following pages you will find questions covering various topics ranging from the structure of molecules, ions, and solids to different models for explaining bonding. Read each question carefully and consider how you will approach it before you put pen or pencil to paper. If you are unsure how to answer one question, then move on to another question; working on a new question may suggest an approach to the one that is more troublesome. If a question requires a written response, be sure that you answer in complete sentences and that you directly and clearly address the question.

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

Question 1 _____/28	Question 4 _____/12
Question 2 _____/12	Question 5 _____/12
Question 3 _____/12	Question 6 _____/12

Question 7 _____/12

Total _____/100

Potentially useful equations and constants are provided here. A periodic table is provided separately.

Potentially Useful Equations

$c = \lambda\nu$ $E = h\nu$ $KE = h\nu - BE$

$$\frac{1}{\lambda} = 1.09737\times10^{-2}\ \text{nm}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$V \propto \frac{Q_+Q_-}{d}$$

$$\text{AVEE} = \frac{xIE_s + yIE_p + zIE_d}{x + y + z}$$

(valence shell electrons only)

$$FC_a = V_a - N_a - \frac{B_a}{2}$$

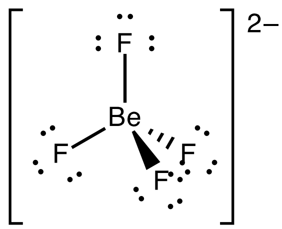
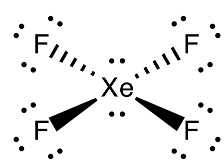
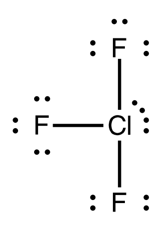
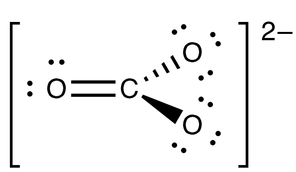
$$\delta_a = V_a - N_a - B_a\left(\frac{EN_a}{EN_a + EN_b}\right)$$

Potentially Useful Constants

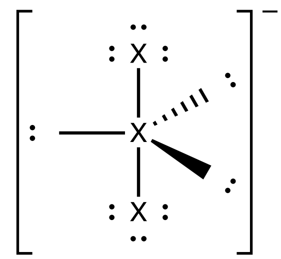
$c = 2.998\times10^{8}$ m/s $h = 6.626\times10^{-34}$ Js $N_A = 6.022\times10^{23}\ \text{mol}^{-1}$

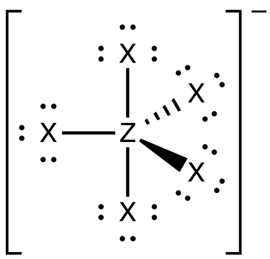
Please write neatly!

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). Provide the name for the bonding geometry around the underlined central atom, predict whether the molecule or ion is polar (P) or non-polar (NP), and provide the idealized bond angle(s) for the stated bond; if there is more than one unique bond angle in your structure, then give the idealized bond angle for each.

Molecule or Ion	Lewis Structure	Bonding Geometry	Polar or Non-Polar?	Ideal Bond Angle(s) for …
$\underline{Be}F_4^{2-}$	There are 2 + 4(7) + 2 = 32 electrons, for which the only possible structure is 	tetrahedral	non-polar	…a F–Be–F bond is…. 109.5°
$\underline{Xe}F_4$	There are 8 + 4(7) = 36 electrons, for which the only possible structure is 	square planar	non-polar	…an F–Xe–F bond is…. 90°
$\underline{Cl}F_3$	There are 7 + 3(7) = 28 electrons, for which the only possible structure is 	t-shaped	polar	…an F–Cl–F bond is…. 90° and 180°
$\underline{C}O_3^{2-}$	There are 4 + 3(6) + 2 = 24 electrons, for which the only possible structure is 	trigonal planar	non-polar	…an O–C–O bond is… 120°

Problem 2. The elements Z and X form the ions ZX_5^- and X_3^-, each consisting of single bonds only. There are five electron domains around both the Z in ZX_5^- and the central X in X_3^-. Identify elements Z and X and, in no more than three sentences, clearly explain your reason for selecting these elements. Note: there are several possible elements for Z and for X; however, you need only provide one example for each.

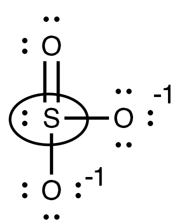




The Lewis structure for X_3^-, which is shown to the right, has 22 electrons. We assign one electron to the negative charge, which leaves 21 electrons for the three Xs; thus, each X has seven valence electrons and is any of the following elements: Cl, Br, I, or At. The Lewis structure for ZX_5^-, which is shown to the left, has 40 electrons. We assign one electron to the negative charge and $7 \times 5 = 35$ electrons to the five Xs; thus, Z has four valence electrons and is any of the following elements: Si, Ge, Sn, or Pb. Note: C and F are not possible choices because they cannot expand beyond an octet and both Z and the central X in X_3^- have 10 electrons around them.

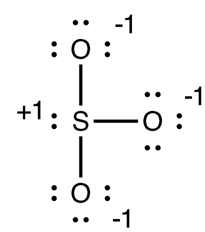
Problem 3. When drawing a Lewis structure sometimes we must choose between a structure that minimizes formal charges and a structure that satisfies the octet rule. Draw two Lewis structures for the sulfite ion, SO_3^{2-}, one that minimizes formal charges and one that satisfies the octet rule. Annotate both structures by specifying the formal charge on each element, by circling any element that does not satisfy the octet rule, and by reporting the bond order between sulfur and oxygen.

<u>Lewis structure that minimizes formal charges</u>



The sulfur-oxygen bond order is 1.33.

<u>Lewis structure that satisfies the octet rule</u>

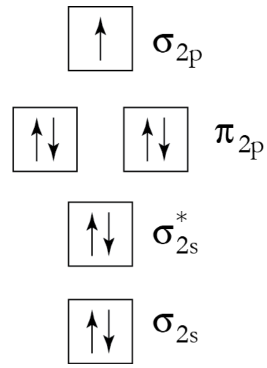


The sulfur–oxygen bond order is 1.00.

Problem 4. The Lewis structure for the ion OCN^- has a single bond between oxygen and carbon and a triple bond between carbon and nitrogen. Describe the O–C bond and the C≡N bond in this ion using the valence bond (hybrid orbital) model. Please limit your answer to no more than four sentences.

The ion OCN^- is linear with C and N each having two sp hybrid orbitals and two p orbitals, and with O having four sp^3 hybrid orbitals. The O–C single bond is a sigma bond resulting from the overlap of an sp^3 hybrid orbital on O with an sp hybrid orbital on C. The C≡N triple bond consists of one sigma bond between an sp hybrid orbital on C and an sp hybrid orbital on N, and two pi bonds between the two p orbitals on C and the two p orbitals on N.

Problem 5. The diagram to the right shows a portion of the molecular orbital diagram for the neutral molecule CX, where C is carbon and X is an element in the periodic table's second row. Identify X? What is the bond order between C and X? Is CX capable of interacting with an applied magnetic field? Explain your answers to these questions in no more than three sentences.



There are nine electrons in the MO diagram, four of which come from C and five of which come from X; thus, X must be N, which has five valence electrons. The bond order between C and X is (7 – 2)/2 = 2.5. Because CX has an unpaired electron in its MOs, it is paramagnetic and will interact with an applied magnetic field.

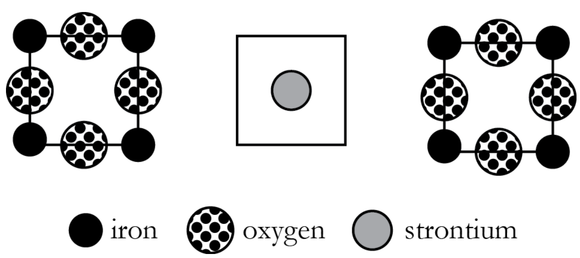
Problem 6. For the ionic compounds KF, CsI, and CaO, identify the one with the lowest melting point and the one with the highest melting point. In no more than three sentences, explain how you arrived at these assignments.

the compound with the lowest melting point is: CsI

the compound with highest melting point is: CaO

For an ionic compound, melting point is related to the force of attraction between the cation and the anion, with a greater force of attraction corresponding to a higher melting point. Using Coulomb's law, we expect CaO to have a higher melting point than KF because of the greater charges on calcium and oxygen (+2/–2) than on potassium and fluorine (+1/–1). We expect KF to have a greater melting point that CsI because K^+ and F^- are smaller than Cs^+ and I^- and, therefore, the distance between K^+ and F^- is smaller than the distance between Cs^+ and I^-. Note: Although ΔEN tells you whether a compound is more ionic-like, and these are all mostly ionic-like compounds, it does not help much in ranking such compounds in terms of melting points; for this, you need to use Coulomb's law.

Problem 7. Shown here are cross-sections, from left-to-right, at $z = 0$, $z = 0.5$, and $z = 1$ through the unit cell of a mineral containing iron (Fe), oxygen (O), and strontium (Sr).



What is the empirical formula for this compound? Place your answer in the space below and indicate how you arrived at this formula by annotating the figure above to show the contribution of each different atom. Based on your empirical formula, what is the oxidation state of iron in this compound?

The eight Fe atoms are on corners and contribute 1/8th each to the unit cell for a total of one Fe atom. The eight O atom are on edges and contribute 1/4th each to the unit cell for a total of two O atoms. One Sr atom is in the center of the unit cell. The empirical formula, therefore, is $FeSrO_2$. The oxidation state of iron is +2 because each oxygen is –2 and strontium is +2.

This unit cell is defined in terms of iron. What is the unit cell's lattice structure? Simple cubic.

Relative to the unit cell's lattice structure, in what type of hole is strontium found? Cubic.

To how many oxygens is each iron coordinated? Justify your answer in one sentence or by sketching a picture. Each iron is coordinated to four oxygen atoms, two in its unit cell and two in adjacent unit cells.