Name:____ Student Number:_______________

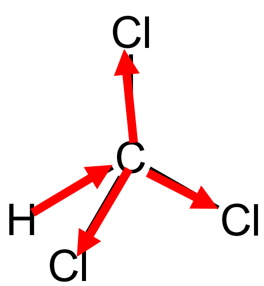
CHEM 1001 A, N and T Midterm Test #2
November 18, 2016
Calculators Allowed
Make sure this test has 7 pages. You may tear off the last page.

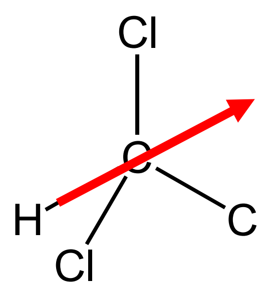
Part A. Answer each of the six questions with a few sentences or equations where necessary. (5 Marks each)

1. AUBAU predicts the ground-state electronic configuration for gold (Au) to be [Xe] $4f^{14}\,6s^{2}\,5d^{9}$, but the actual configuration is different. What do you think it actually is and why?

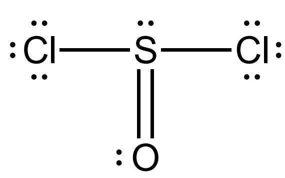
   It is actually [Xe] $4f^{14}\,6s^{1}\,5d^{10}$. By moving one electron from the 6s to the 5d subshell, the atom attains one filled and one half-filled subshell, which are collectively at a lower energy than a filled 6s and $9/10^{ths}$ filled 5d subshells.

2. Draw correctly oriented dipoles on each bond in the tetrahedral molecule of $CHCl_3$ shown at the left below. Then draw the overall dipole on the one at the right.





3. A Lewis diagram for $SOCl_2$ is shown below. What is the ideal Cl-S-O bond angle in this molecule and why?

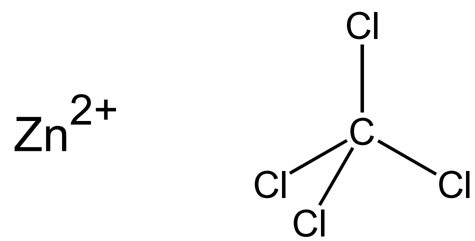


   The central S atom has a steric number of four, and so has a tetrahedral arrangement of charge clouds around it. The ideal bond angle must therefore be 109.5°.

4. When a molecule of F_2 is ionized to F_2^+, the bond becomes shorter and stronger. What can you conclude about the molecular orbital from which the electron was removed? Why?

The electron must have been removed from an antibonding molecular orbital. This would cause the bond order to increases, making the bond shorter and stronger.

5. What is the strongest intermolecular force between the two species shown below?



An ion - induced dipole force is the largest intermolecular force between these two species.

6. Why is the second ionization energy of an atom always larger than the first?

In the first ionization, an electron is being separated from a singly charge cation. In the second ionization, an electron is being removed from a doubly charged cation. The attractive force in the latter is larger, so the ionization energy is larger too.

Part B. Answer any three of the following four questions (B1, B2, B3, B4). If you answer all four, the best three answers will count. (20 marks each)

B1. [20 marks] Use the following data to calculate the second ionization energy of magnesium (Mg).

$$\Delta H_o^f(MgF_{2(s)}) = -1124 \text{ kJ mol}^{-1}$$
$$\Delta H_{sub}(Mg_{(s)}) = 150 \text{ kJ mol}^{-1}$$
$$I_1(Mg) = 738 \text{ kJ mol}^{-1}$$
$$BDE(F_2) = 158 \text{ kJ mol}^{-1}$$
$$EA(F_2) = -322 \text{ kJ mol}^{-1}$$
$$U(MgF_{2(s)}) = 2913 \text{ kJ mol}^{-1}$$

15 marks for setting it up correctly. 5 marks for the arithmetic.

$Mg_{(s)} \rightarrow Mg_{(g)}$	+150 kJ mol^{-1}
$Mg_{(g)} \rightarrow Mg^{+}_{(g)} + e^-$	+738 kJ mol^{-1}
$Mg^{+}_{(g)} \rightarrow Mg^{2+}_{(g)} + e^-$	?? kJ mol^{-1}
$F_{2(g)} \rightarrow 2\ F_{(g)}$	158 kJ mol^{-1}
$2\ F_{(g)} + 2\ e^- \rightarrow 2\ F^-_{(g)}$	2(-322 kJ mol^{-1})
$Mg^{2+}_{(g)} + 2\ F^-_{(g)} \rightarrow MgF_{2(s)}$	-(2913 kJ mol^{-1})

$Mg_{(s)} + F_{2(g)} \rightarrow MgF_{2(s)}$	-1124 kJ mol^{-1}

Thus, -1124 = (150 + 738 + ?? + 158 + 2(-322) + (-2913))

?? = -1124 – 150 – 738 – 158 -2(-322) + 2913

= 1387 kJ mol^{-1}

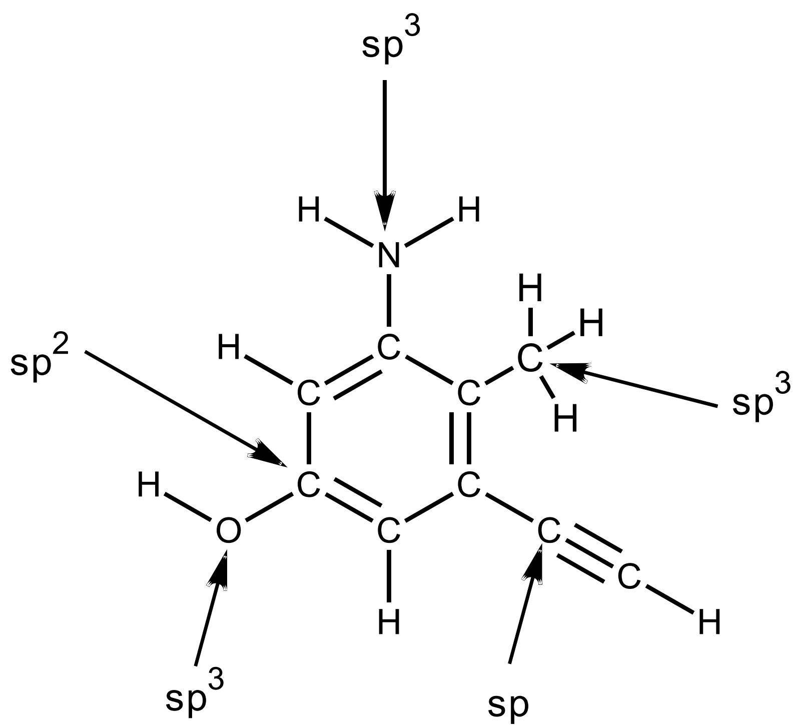
B2. (a) [5 marks] Use VSEPR theory to predict the shape of BrF_5. Wrong name = zero marks.

7 + (5 x 7) = 42 electrons. Arranging the five F atoms around the central Br atom and making two-electron bonds uses 10 electrons. Completing the octets on the F atoms uses another 30 for a total of 40. The last two electrons are placed as a lone pair on the central Br atom. The shorthand notation is therefore AX_5E, which is **Square Pyramidal.**

(b) [5 marks] Use VSEPR theory to predict the shape of Cl_3^-. Wrong name = zero marks.

(3 x 7) + 1 = 22 electrons. Arranging two Cl atoms around the third one and making two-electron bonds uses 4 electrons. Completing the octets on the terminal Cl atoms uses another 12 for a total of 16. The last 6 electrons are placed as three lone pairs on the central Cl atom. The shorthand notation is therefore AX_2E_3, which is **Linear**.

(c) [10 marks] In each box, write the type of hybrid orbitals the indicated atom is using:



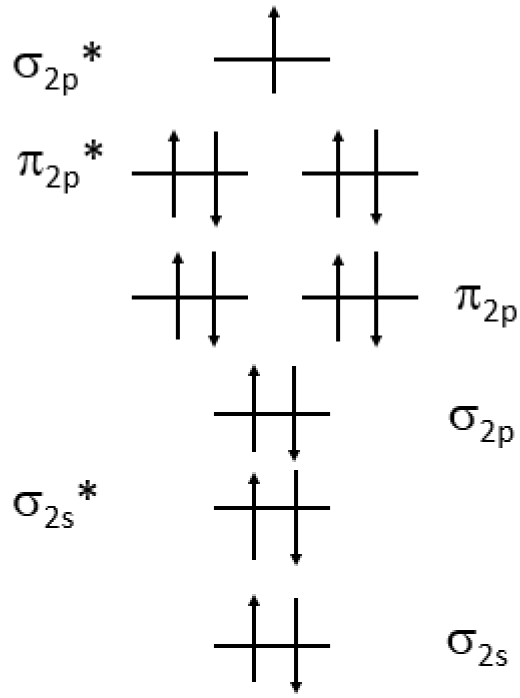
B3. Use the molecular orbital diagram for Ne_2^+ below to answer the following questions:

(i) [3 marks] Calculate the bond order of Ne_2^+.

Bond order = (8 – 7)/2 = 0.5

(ii) [3 marks] Is Ne_2^+ paramagnetic or diamagnetic? Why?

Ne_2^+ is paramagnetic because of the unpaired electron in the σ_{2p}* molecular orbital.



(iii) [3 marks] Calculate the bond order of Ne_2^{2+}

Bond order = (8 – 6)/2 = 1

(iv) [3 marks] Would Ne_2^{2+} be paramagnetic or diamagnetic? Why?

Ne_2^{2+} would be diamagnetic because to make it requires removing the single electron from the σ_{2p}* MO, leaving all others paired up.

(v) [4 marks] Which of Ne_2^+ or Ne_2^{2+} has the greater bond length? Why?

Ne_2^+ has a greater bond length than Ne_2^{2+} because it has a smaller bond order.

(vi) [4 marks] Which of Ne_2^+ or Ne_2^{2+} has the greater bond energy? Why?

Ne_2^{2+} has a greater bond energy than Ne_2^+ because it has a larger bond order.

B4. (a) [8 marks] Lead (Pb) metal cystallizes in a face centred cubic structure. The density of lead metal is 11.34 g cm^{-3}. Calculate the radius of a lead atom (pm).

$$\text{Unit cell mass} = m = 4\left(\frac{207.2\,\text{g mol}^{-1}}{6.02\times10^{23}\,\text{mol}^{-1}}\right) = 1.38\times10^{-21}\,\text{g}$$

$$\text{Unit cell volume} = V = \frac{m}{\rho} = \frac{1.38\times10^{-21}\,\text{g}}{11.34\,\text{g cm}^{-3}} = 1.22\times10^{-22}\,\text{cm}^3$$

$$\text{Unit cell edge length} = l = \sqrt[3]{V} = \sqrt[3]{1.22\times10^{-22}\,\text{cm}^3} = 4.96\times10^{-8}\,\text{cm}$$

$$\text{Radius} = r = \sqrt{\frac{l^2}{8}} = \sqrt{\frac{(4.96\times10^{-8}\,\text{cm})^2}{8}} = 1.75\times10^{-8}\,\text{cm}$$

$$= 175\,\text{pm}$$

<u>OR</u>

$$\text{Volume per g of Pb metal is } \frac{1}{\left(\frac{11.34\text{ g}}{\text{cn}^3}\right)} = 0.0882\text{ cm}^3\text{g}^{-1}$$

$$\text{Volume per mol of Pb metal is } 0.0882\text{ cm}^3\text{g}^{-1}(207.2\text{ g mol}^{-1}) = 18.27\text{ cm}^3\text{mol}^{-1}$$

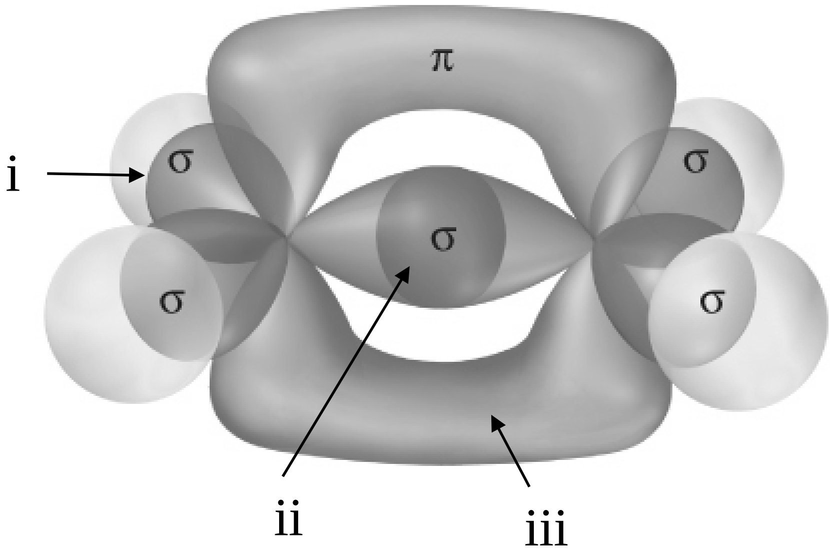
$$\text{Volume per mol of Pb atoms is } 74\%(18.27\text{ cm}^3\text{mol}^{-1}) = 13.52\text{ cm}^3\text{mol}^{-1}$$

(since FCC structures are 74% occupied by the atoms)

$$\text{Volume per Pb atom is } \frac{13.52\text{ cm}^3\text{mol}^{-1}}{6.02\times10^{23}\text{mol}^{-1}} = 2.246\times10^{-23}\text{cm}^3$$

$$\text{Radius of a spherical Pb atom is} \left(\frac{V}{\frac{4}{3}\pi}\right)^{1/3} = \left(\frac{2.246\times10^{-23}\text{cm}^3}{\frac{4}{3}\pi}\right)^{1/3} = 1.75\times10^{-8}\text{cm} = 175\text{ pm}$$

(b) [12 marks] Referring to the drawing of an ethylene molecule (C_2H_4):



Bond (i) is a_sigma (σ)_bond formed by the overlap of a _1s_ orbital on the H-atom with a _sp^2_ orbital on the C-atom

Bond (ii) is a _ sigma (σ)_ bond formed by the overlap of a_sp^2_ orbital on one C-atom with a _sp^2_ orbital on the other C-atom

Bond (iii) is a _pi (π)_ bond formed by the overlap of a _2p_ orbital on one C-atom with a _2p_ orbital on the other C-atom