CHEM101/3, D1	Mid Term Review Questions
	Answers

Note: In general I'm satisfied w/ 2 or 3 sig. fig.'s; so that's what's used in this answer sheet.

1.) Supply the missing names or formulas:

a. aluminum sulfite $Al_2(SO_3)_3$

b. chlorous acid HClO₂

- c. AuBr₃ gold(III) bromide
- d. N₂O₃ dinitrogen trioxide
- 2.) A compound contains only C, H and N. Combustion of 2.103 mg of the compound produced 5.840 mg CO₂ and 1.200 mg H₂O. What is the empirical formula of the compound?

mass of C:

5.84 mg CO₂ x $\frac{1 \text{ mmol CO}_2}{44 \text{ mg CO}_2}$ x $\frac{1 \text{ mmol C}}{1 \text{ mmol CO}_2}$ x $\frac{12 \text{ mg C}}{1 \text{ mmol C}}$ = 1.60 mg C

mass of H:

 $1.20 \text{ mg } \text{H}_2\text{O} \text{ x } \frac{1 \text{ mmol } \text{H}_2\text{O}}{18.0 \text{ mg } \text{H}_2\text{O}} \text{ x } \frac{2 \text{ mmol } \text{H}}{1 \text{ mmol } \text{H}_2\text{O}} \text{ x } \frac{1.01 \text{ mg } \text{H}}{1 \text{ mmol } \text{H}} = 0.134 \text{ mg } \text{H}$

mass of N : difference between "total" and "C" and "H".

2.10 mg - (1.60 mg + 0.134 mg) = 0.375 mg N

	mass (g)	mmoles	divide by lowest "mmoles", 0.0268	nearest integer ratio
С	1.60	0.133		5.0
Н	0.134	0.133		5.0
Ν	0.375	0.0268		1

 $\therefore C_5H_5N$

3.) Hydrogen cyanide is produced industrially from the reaction of gaseous ammonia, oxygen and methane: 2 NH_{3 (g)} + 3 O_{2 (g)} + 2 CH_{4 (g)} → 2 HCN (g) + 6 H₂O (g) If 120 kg of ammonia, 300 kg of oxygen and 150 kg of methane were used, calculate the amount (in kg) of hydrogen cyanide produced assuming the reaction efficiency is 80%. Use the following molar masses: NH₃ = 17.031 g/mol, O₂ = 32.000 g/mol, CH₄ = 16.043 g/mol, HCN = 27.026 g/mol, H₂O = 18.016 g/mol

Determine amt of product from each reactant:

 $120 \text{ kg NH}_3 \text{ x } \frac{1 \text{ kmol NH}_3}{17.0 \text{ kg NH}_3} \text{ x } \frac{2 \text{ kmol HCN}}{2 \text{ kmol NH}_3} = 7.05 \text{ kmol HCN}$ $300 \text{ kg O}_2 \text{ x } \frac{1 \text{ kmol O}_2}{32.0 \text{ kg O}_2} \text{ x } \frac{2 \text{ kmol HCN}}{3 \text{ kmol O}_2} = 6.25 \text{ kmol HCN}$ $150 \text{ kg NH}_3 \text{ x } \frac{1 \text{ kmol CH}_4}{16.0 \text{ kg CH}_4} \text{ x } \frac{2 \text{ kmol HCN}}{2 \text{ kmol CH}_4} = 9.35 \text{ kmol HCN}$

O2 is L.R. (limiting reactant), since it produces the least amt of product.

Actual yield:

6.25 kmol HCN x
$$\frac{27.0 \text{ kg HCN}}{1 \text{ kmol HCN}}$$
 x 0.8 = 135 kg HCN
from 80% yield

HT

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4.) Draw the correct Lewis dot structure and indicate the expected geometry around each central atom. To receive full marks, indicate the number of valence electrons, the number of unshared electrons and formal charges for each atom. If necessary, draw resonance structures.

a.
$$HCO_3^-$$

 $N_t = 1 + 4 + (3 \times 6) + 1 = 24$



Total # of lone pairs (= unshared e^{-s}) in the most reasonable resonance structures = 7

Geometry acc. to VSEPR:

on C : 3 e^- groups; therefore, trigonl planar e^- and ${\bf atom}$ arrangement

on O carrying the H: 4 e^- groups; therefore, tetrahedral e^- arrangement and bent atom arrangement.

b. Briefly explain why the HOH bond angle in water is smaller than the HNH bond angle in ammonia. Indicate which theory you are basing your explanation on.

Lone pairs (LP) require more space than bonding pairs (BP) and will "squeeze" the bonding angle.

 ${
m H}_2{
m O}$ has 2 LP's, while NH₃ has only 1 LP.

Consequently, the bonding angle in H_2O is somewhat smaller.

5.) a. Write the electron configuration for tin.

[Kr] $5s^24d^{10}5p^2$

b. Give the maximum number of e^- 's in an atom that can have these quantum numbers: n=5 and $m_\ell=+2.$

OK, the question is somewhat ambiguous. Let's reword it:

We deal with an atom that has all orbitals up to n = 5 occupied with e^{-1} 's.

How many e⁻'s are in orbitals where $m_{\ell} = +2$?

The quantum number ℓ must be at least 2 to have m_{ℓ} = +2 orbitals and n could be 3, 4 or 5. So, we get the following tabulation for m_{ℓ} = +2 orbitals:

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- $n=3,\,\ell=2,\,m_\ell=+2$
- $n=4, \ \ell=2, \ m_\ell=+2$
- $n=4,\,\ell=3,\,m_{\ell}=+2$
- $n=5,\,\ell=2,\,m_\ell=+2$
- $n=5,\,\ell=3,\,m_{\ell}=+2$
- $n=5, \ \ell=4, \ m_\ell=+2$
- That's a total of 6 orbitals which can accommodate 12 e⁻'s.
- c. Find the wavelength corresponding to the removal (to infinity) of an electron

in the hydrogen atom that is initially at n = 4.

transition n = 4 to $n = \infty$; Z = 1 for H

$$\Delta E \; = \; h \nu; \; \; \nu \; = \; \frac{\Delta E}{h} \; ; \qquad \lambda = \; \frac{c}{\nu} \;$$

$$v = \frac{\Delta E}{h} = \frac{-2.18 \text{ x } 10^{-18} \text{ J } (0 - 1/4^2)}{6.63 \text{ x } 10^{-34} \text{ Js}} = 2.05 \text{ x } 10^{14} \text{ s}^{-1}$$

$$\lambda = \frac{c}{\nu} = \frac{3.00 \text{ x } 10^8 \text{ ms}^{-1}}{2.05 \text{ x } 10^{14} \text{ s}^{-1}} = 1.46 \text{ x } 10^{-6} \text{ m} = 1.46 \text{ } \mu\text{m}$$

6.) a. Give/Explain in your words: Hund's rule.

In general, if orbitals are degenerate (have same energy) they will be filled singly first (with spin aligned in the same direction) before being filled doubly.,

b. Explain the bonding and hybridization in CO₂. Using Lewis theory we find

Acc. to VSEPPR there are 2 e^- groups on C; therefore we get linear electron and atom arrangement around C.

Acc to VB theory, C is sp hybridized leaving 2 unhybridized p AO's. The sp orbitals form σ bonds while the p orbitals form π bonds No hybridization on the terminal O's. Therefore, each C,O double bond consists of a (sp,p) σ bond and a (p,p) π bond. 7.) Consider the acetylide anion, C_2^{2-} , and analyze it by various bonding theories.

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a. Derive its Lewis structure.

 $N_t = (2 x 4) + 2 = 10$

$$N_0 = 14 \text{ from}$$
 :C---C:

remove 4 e⁻'s; try to obey octet rule

$$:\overset{\cdots}{c}\overset{\cdots}{=}\overset{\circ}{c}:\longrightarrow:\overset{\Theta}{c}\overset{\Theta}{=}\overset{\Theta}{c}:$$

b. What are the number of e⁻ groups around each C?

2; a triple bond and a lone pair

c. Are there any formal charges? If so, where?

yes, as indicated under a.

d. Describe the bonding acc. to the VB theory.

There are two possibilities: with and without hybridization. Try your hands at both.

- If we allow hybridization, we would say that the C atoms are sp hybridized. Consequently, the C atoms are bound by a (sp,sp)σ bond and 2 (p,p)π bonds. The lone pairs occupy sp hybrid orbitals.
- ii. If we consider the C atoms terminal and don't allow hybridization,

we form a $(p,p)\sigma$ bond and two $(p,p)\pi$ bonds.

The lone pairs would be located in unhybridized s orbitals.

We don't commit here; in an exam I would allow both answers.

e. Sketch the MO energy diagram, label the energy levels and



f. Assess magnetic properties by MO theory.

All e⁻'s are paired; therefore, the anion is diamagnetic.

- Application of MO theory. For the following species sketch those bonding MO's that are not cancelled by antibonding orbitals,
 - a. Li_2 b. C_2^{2-}
 - a.) In Li₂, a σ MO is formed from 2 originating 2s AO's. This looks similar to the σ MO in H_2
 - b.) In C_2^{2-} , the relevant bonding MO's are σ_{2pz} , π_{2px} and π_{2py} . If we align, the C,C bond with the z axis; then the MO's look roughly as shown below.







b.

b. Which of them are related by resonance. Explain.

a.

b.) and c.) are related by resonance. The connectivities are the same ;

only the location of e⁻'s has changed: bonding e⁻'s have become lone pairs and v.v.

In a.) the connectivity (atom skeleton) is clearly different;

e.g., the left hand C in a.) is connected to 2 H's, while in b.) it is connected to 3 H's.

c. Which of those related by resonance contributes most to the resonance hybrid?

In both structures we have octets everywhere and both have one F.C. = -1.

In c.) the neg. charge is located on the more e/n atom,

so we expect this structure to contribute more.

c.