CHEM 101, B2 **Sample Final Exam** 2008 04 03 HT

Answers

This is, in large part, a sample final exam from a colleague of mine.

The Chemistry Data sheet will be identical to the one we had for the MidTerm Exam.

This sample is for orientation only; the actual exam might be substantially different; it probably will have more concept questions, rather than calculation problems.

This is a **closed book exam**.

You may use a non-programmed calculator and the provided Chemistry Data Sheet.

1 a) Write the chemical formula for aluminum sulfite. *$Al_2(SO_3)_3$*
(1 mark)

1 b) Write the chemical formula for nitrous acid. *HNO_2 or $HNO_2(aq)$*
(1 mark)

1 c) Write the chemical formula for iron (III) oxide. *Fe_2O_3*
(1 mark)

1 d) Give the correct name for $AuCl_3$. *gold(III) chloride*
(1 mark)

1 e) Give the correct name for $K_2Cr_2O_7$. *potassium dichromate*
(1 mark)

1 f) Give the correct name for $NaHCO_3$. *sodium hydrogen carbonate*
(1 mark)

2) Adipic acid contains 49.32% of carbon, 43.84% of oxygen and 6.85% of hydrogen, (all percentages being by weight). A different experiment showed that the molar mass of adipic acid is between 130 and 160 g/mol. Find the empirical and molecular formulas of adipic acid?

atom	mass (g)	moles	ratio	x2 & round
C	49.32	4.11	1.50	3
O	43.84	2.74	1.00	2
H	6.85	6.80	2.48	5

- empirical formula : $\underline{\underline{(C_3H_5O_2)}}$
- empirical formula mass : 73.1 g/mol
- molar mass is about twice this value

$\therefore$ molecular formula : $\underline{\underline{C_6H_{10}O_4}}$

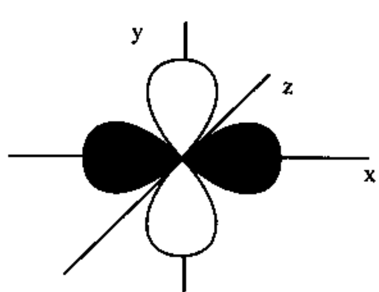
3a) What is the maximum number of electrons in an atom that can have $n = 3$ and $m_\ell = \pm 1$?

n = 3 can have: $\ell = 1$ *with* $m_\ell = -1$ *and* $m_\ell = +1$ *, and*

$\ell = 2$ *with* $m_\ell = -1$ *and* $m_\ell = +1$

for a total of 4 atomic orbitals that can accommodate $\boxed{\text{8 electrons}}$

3b) Draw the $d_{x^2-y^2}$ orbital. Make sure to label the axes properly.



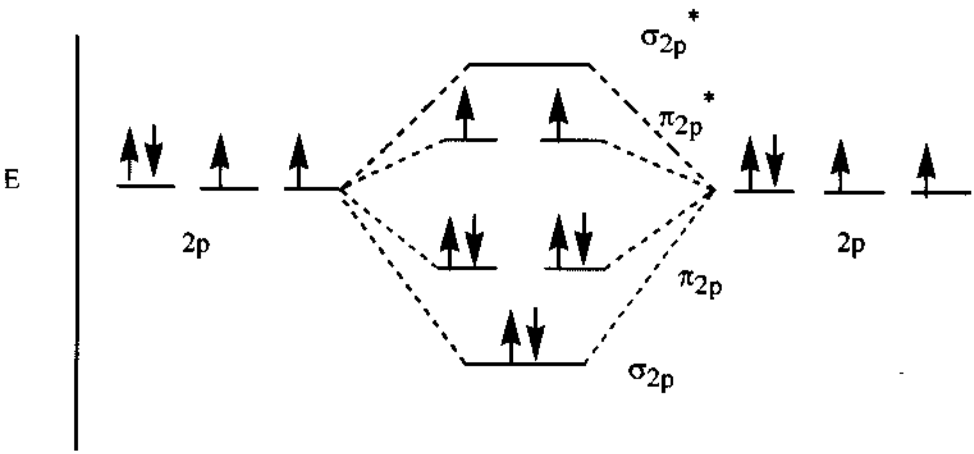
The lobes line up with the x and y axes.

4) Using MO theory, draw the MO energy diagram for O_2 labeling all orbitals.

(You can omit lower MO that cancel out).

Then rank the following species in terms of stability: O_2, O_2^-, O_2^+. Briefly explain your answer.

For O_2 we can use the the "expected" MO energy diagram



O_2 (shown in figure)

$$\textbf{Bond order} = \frac{\textbf{bonding e}^- - \textbf{antibonding e}^-}{2} = \frac{6-2}{2} = 2$$

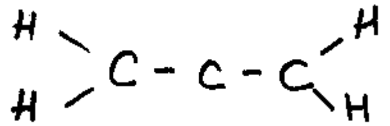
O_2^- one extra e^- than O_2 in antibonding MO **Bond order** $= \frac{6-3}{2} = 1.5$

O_2^+ one fewer e^- than O_2 in antibonding MO **Bond order** $= \frac{6-1}{2} = 2.5$

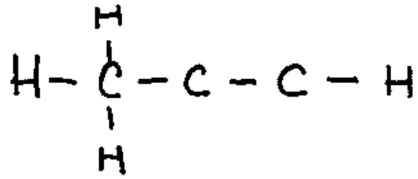
Most stable $\underline{O_2^+ > O_2 > O_2^-}$ **least stable**

5a) Draw the correct Lewis dot structure for C_3H_4. 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. Indicate the geometries around the central atoms of all structures.

Two different connectivities are possible

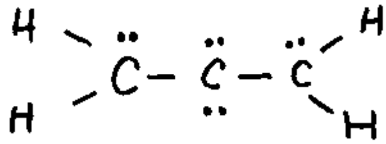


and



For both cases $N_t = (3 \times 4) + (4 \times 1) = 16\ e^-$

Octets every where :



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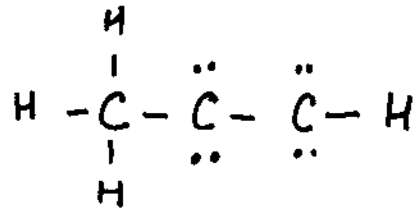
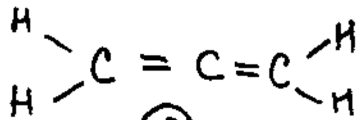


For both cases, $N_O = 20\ e^-$;

must remove $4e^-$ & form multiple bonds:



(A)

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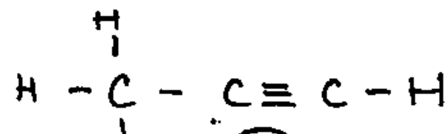


(B)

No FC's anywhere.

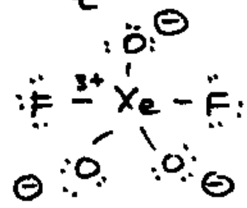
outer C's : sp^2, trigonal planar	left C : sp^3, tetrahedral
middle C : sp, linear	other C's : sp, linear

5b) How would it be possible to distinguish between possible structures in a.

(A) is symmetrical, therefore non polar.
(B) is asymmetrical and we expect the molecule to be polar.
∴ Determination of polarity should give the answer

6a) Draw the correct Lewis dot structure for XeO_3F_2. To receive full marks, indicate the number of valence electrons, the number of unshared electrons and formal charges for each atom.

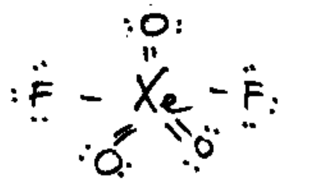
$N_t = 8 + (3 \times 6) + (2 \times 7) = 40\,e^-$



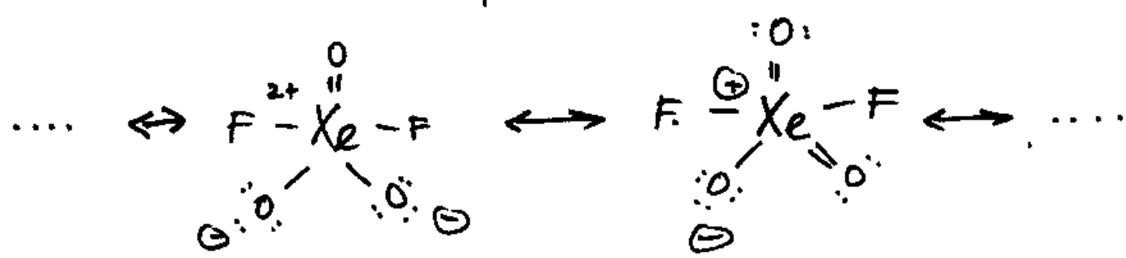
$N_o = 40\,e^-$; Xe has $10\,e^-$, allowed

FC's : Xe : $+3$, all O's : -1

FC's can be reduced by forming double bonds :



; Existence of various resonance forms is probably a better expression :

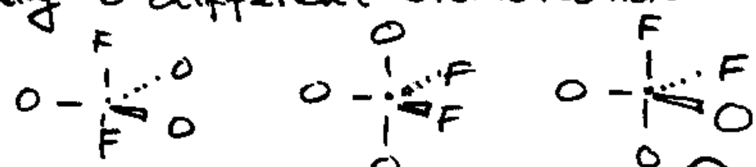


6b) What is the name for the geometry of the above structure and do you expect it to be polar or non polar?

Based on VSEPR : 5 e^- groups $\rightarrow$ trigonal bipyramidal geometry.

(translates into sp^3d hybridization of central atom).

Potentially 3 different stereoisomers could be envisaged.



A B C

A is symmetrical, nonpolar; B & C asymmetrical, polar.

There is a rule (not covered by me; therefore I wouldn't ask it) that more e/n atoms go into the axial position.

Consequently, A would be favored & we expect XeO_3F_2 to be non polar.

7. a) Write the electronic configuration for lead. Do not use the abbreviated notation !

Pb $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^2$

b) Explain why the second ionization energy of nitrogen is smaller than that of oxygen but the first ionization energy of nitrogen is larger than that of oxygen!

Key to understanding :
half filled shells (in this case p shells)
provide a certain amount of stability ;
therefore removal of an e^- from such a configuration
is relatively more difficult (=" larger IE ")

i) IE_1

$N \rightarrow N^+ + e^-$ $\qquad$ $O \rightarrow O^+ + e^-$

$[He]\,2s^2\,2p_x^1\,2p_y^1\,2p_z^1$ $\qquad$ $[He]\,2s^2\,2p_x^2\,2p_y^1\,2p_z^1$

↑
p shell half filled
∴ Larger IE

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ii) IE_2

$N^+ \rightarrow N^{2+} + e^-$ $\qquad$ $O^+ \rightarrow O^{2+} + e^-$

$[He]\,2s^2\,2p_x^1\,2p_y^1$ $\qquad$ $[He]\,2s^2\,2p_x^1\,2p_y^1\,2p_z^1$

↑
p shell half filled
∴ larger IE .

8) A sample of potassium chlorate, $KClO_3$, is impure, being mixed with sodium sulfate. When the sample is heated, the $KClO_3$ decomposes completely to give oxygen gas and potassium chloride, and the sodium sulfate is not changed. 2.38 g of the sample were heated and produced 537 mL of oxygen gas collected over water at 25°C and total pressure of 697 torr.

a. How many moles of oxygen gas were produced?

$$2\ KClO_3 \rightarrow 2\ KCl + 3\ O_{2\,(g)}$$

$$P_{O_2} = P_{total} - P_{water}^{25\,°C} = 697 - 23.8 = 673.2 \text{ torr } (\times\ 101.3 \text{ kPa} / 760 \text{ torr} = 89.7 \text{ kPa})$$

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(89.7 \text{ kPa})(0.537 \text{ L})}{(8.31 \text{ kPa L mol}^{-1} \text{K}^{-1})(298 \text{ K})} = \boxed{0.0194 \text{ mol } O_2}$$

b. What was the weight percent of $KClO_3$ in the sample?

Find mass of $KClO_3$ in the sample from stoichiometry

$$m_{KClO_3} = 0.0194 \text{ mol } O_2 \ \frac{2 \text{ mol } KClO_3}{3 \text{ mol } O_2} \ \frac{122.55 \text{ g } KClO_3}{1 \text{ mol } KClO_3} = 1.58 \text{ g } KClO_3$$

$$\text{Percent } KClO_3 = \frac{1.58 \text{ g}}{2.38 \text{ g}}\ 100\% = \boxed{66.6\%}$$

9) a. List 3 assumptions made in the kinetic molecular theory of ideal gases

Continuous random motion

Negligible size of molecules compared to the distance between them

No attraction/repulsion forces between molecules

Collisions are elastic (no permanent deformation of molecules)

3 of the above are OK

b. The vapor pressure of bromine is larger than that of mercury (both liquids at room temperature). Which liquid has a higher boiling point? Explain briefly.

$\boxed{\textbf{Hg}}$

Higher vapor pressure (Br_2) $\Rightarrow$ weaker intermolecular forces $\Rightarrow$ lower b.p

10) Identify the main intermolecular forces in the following molecules and rank them in order of strength. (To avoid confusion, list them in order and clearly indicate the strongest). Briefly explain your answer.

$\mathrm{CH_3\overset{\overset{O}{\|}}{C}OH}$, iodobenzene C_6H_5I and NH_4NO_3.

$\mathrm{CH_3\overset{\overset{O}{\|}}{C}OH}$	$\boxed{\textbf{H – bonding.}}$
iodobenzene C_6H_5I	**Only slightly polar. Main forces are** $\boxed{\textbf{London dispersion forces.}}$
NH_4NO_3	$\boxed{\textbf{Ionic}}$

$$\boxed{NH_4NO_3 > \mathrm{CH_3\overset{\overset{O}{\|}}{C}OH} > C_6H_5I}$$

11.) Tungsten has a body-centered cubic crystal structure. Using a metallic radius of 139 pm for W, calculate the density for tungsten.

Approach:

- m/V for unit cell = density
- # of W atoms per unit cell → mass of unit cell
- determine volume of W atom; knowing packing efficiency, can determine V of unit cell.

- $m = \frac{MM}{N_A} = \frac{184 \text{ g/mol}}{6.02 \times 10^{23} \text{ atoms/mol}} = 3.06 \times 10^{-22} \text{ g/atom}$

- bcc has 2 W atoms → 6.12×10^{-22} g / unit cell

- V of 1 W atom $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \left(139 \text{ pm} \times \frac{10^{-12} \text{ m}}{1 \text{ m}}\right)^3$

$$= 1.12 \times 10^{-29} \text{ m}^3$$

- $PE = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}} = 0.680$ for bcc

$$V(\text{unit cell}) = \frac{V(\text{atoms})}{PE} = \frac{2 \times (1.12 \times 10^{-29} \text{ m}^3)}{0.68}$$

$$= 3.29 \times 10^{-29} \text{ m}^3$$

- $D = \frac{m}{V} = \frac{6.12 \times 10^{-22} \text{ g}}{3.29 \times 10^{-29} \left(\text{m} \times \frac{100 \text{ cm}}{1 \text{ m}}\right)^3} = \underline{18.6 \frac{\text{g}}{\text{cm}^3}}$