ANSWER KEY MIDTERM 3
F1404 2003

1) Fill in the blanks: (9 points)

a) When n = 2, the value(s) of l can be: 0, 1 (1)

b) When l = 1, the value(s) of m_l can be: −1, 0, +1 (1) and the subshell has the letter label: p (1)

c) When l = 2, the subshell is called a d (1) subshell.

d) When a subshell is labeled s, the value of l is 0 (1) and m_l has the value 0 (1).

e) When a subshell is labeled p, 3 (1) orbitals occur within the subshell

f) When a subshell is labeled f, there are 7 (1) values of m_l, and 7 (1) orbitals occur within the subshell.

2) How many electrons can have the following quantum numbers in an atom? For each show how you came to your answer (You will not get full credit if you just put a number down)

a) n = 2, l = 1 (3 points)

n	l	me	ms	Number of electrons
2	1	−1	± 1/2	2
		0	± 1/2	2
		+1	± 1/2	2

(2 points)

Total = 6 (1 point)

b) n = 4, l = 2, m_l = -2 (3 points)

n	l	me	ms	# of electrons
4	2	−2	± 1/2	2

(2 pts)

Total # of electrons = 2 (1 pt)

c) n = 3 (3 points)

n	l	me	ms	# of electrons
3	0	0	± 1/2	2
	1	−1, 0, +1	± 1/2	6
	2	−2, −1, 0, +1, +2	± 1/2	10

(2 pts)

Total # of electrons = 18 (1 pt)

3) Which of the following statements are true? If false, briefly explain (in two sentences or less) why they are false.

a) It takes less energy to extract a s electron than a p electron in the same shell. (3 points)

① FALSE.

② An s electron is more tightly bound than a p electron in the same shell, since a s electron penetrate closer to the nucleus than a p electron, feeling a stronger interaction with the nucleus.

b) Electrons in $l = 2$ subshells are better at screening nuclear charge than electrons in $l = 1$ subshells. (3 points)

① FALSE

② $l = 2$, or d-electrons do not penetrate inner shells as much as $l = 1$, or p electrons; and hence are less effective at screening the nuclear charge

c) The effective nuclear charge, Z_{eff}, experienced by an electron in a p-orbital is higher than for an electron in a s-orbital in the same shell. (3 points)

① FALSE

② A s electron penetrates closer to the nucleus than a p electron and hence a s electron experiences a higher nuclear charge than a p electron in the same shell

4) Determine whether the following electron configurations represent the ground state or excited state of the atom given

(a) C 1s [$\uparrow\downarrow$] 2s [$\uparrow\downarrow$] 2p [$\uparrow\downarrow$][ ][ ]

(b) N 1s [$\uparrow\downarrow$] 2s [$\uparrow\downarrow$] 2p [$\uparrow$][$\downarrow$][$\uparrow$]

(c) Be 1s [$\uparrow\downarrow$] 2s [$\uparrow$] 2p [$\uparrow$][ ][ ]

(d) O 1s [$\uparrow\downarrow$] 2s [$\uparrow\downarrow$] 2p [$\uparrow\downarrow$][$\uparrow$][$\uparrow$]

If any of the electron configurations represent an excited state then draw the ground state electron configuration for that atom.

4 a) C excited state shown ① (3 points)

Ground state of C 1s [$\uparrow\downarrow$] 2s [$\uparrow\downarrow$] 2p [$\uparrow$][$\uparrow$][ ] ②

4 b) N Excited state (3 points)

Ground state [↑↓] [↑↓] [↑|↑|↑]
1s 2s 2p

4 c) Be Excited State (3 points)

[↑↓] [↑↓] [| |]
1s 2s 2p

4 d) O Ground state (3 points)

5) The observed ground state electronic configuration for Cr is $[Ar]3d^5 4s^1$ and that for Cu is $[Ar]\ 3d^{10}4s^1$. These observed electronic configurations are different than what would be expected for these elements based on their positions in the periodic table.

5a) What would the ground state electronic configuration for Cr and Cu be based solely on their positions in the periodic table? (4 points)

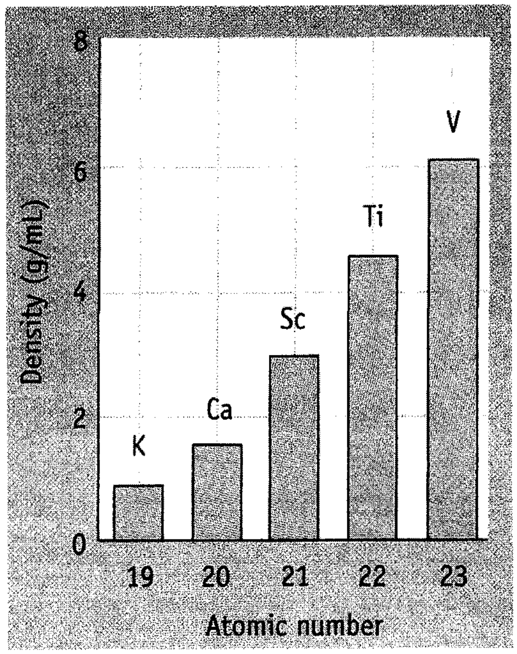
Cr: $[Ar]\ 3d^4\ 4s^2$ (2)

Cu: $[Ar]\ 3d^9\ 4s^2$ (2)

5b) Why are the observed ground state electronic configurations preferred to the electron configurations predicted in 5a? (5 points)

For Cr the observed electron configuration results in a half filled d orbital; for Cu the observed electron configuration results in a completely filled d orbitals which are energetically more stable electron configurations.

6) Using your knowledge of periodic trends briefly explain the reason(s) for the observed trend in the density of the elements from K through V as shown in the plot below. (8 points)



Across a period size of the atom decreases, hence volume decreases. However mass increases across the period

Since Density = $\frac{M}{V}$ and M is increasing and V decreasing across a period, expect density to increase as revealed in the plot above

7) Using valence bond theory, describe the bonding in the hydrogen cyanide molecule (HCN). If the atomic orbitals of any of the atoms in HCN undergo hybridization, describe the kind of hybridization, and using orbital box notation indicate the occupancy of pure and hybrid orbitals. For each bond in HCN indicate the kind of orbitals overlapping and if the resulting bond is a σ or π bond. If any of the atoms have lone pair electrons, indicate the kind of orbital that the lone pair electrons occupy.

(15 points)

Lewis dot structure H — C ≡ N: (1)

Both C and N are sp hybridized

C $1s^2 2s^2 2p^2$

Focus on valence electrons

[↑↓] [↑|↑|]

$2s^2$ $2p^2$

↓ sp hybridization

[↑|↑] [↑|↑]

sp p

N $1s^2 2s^2 2p^3$

[↑↓] [↑|↑|↑]

$2s^2$ $2p^2$

↓ sp hybridization

[↑↓|↑] [↑|↑]

sp p

(5)

H — C ≡ N:

H–C bond is a σ bond overlap between H_{1s} and C_{sp}

H–C bond is a σ bond; of the three bonds between C≡N, one σ, two π

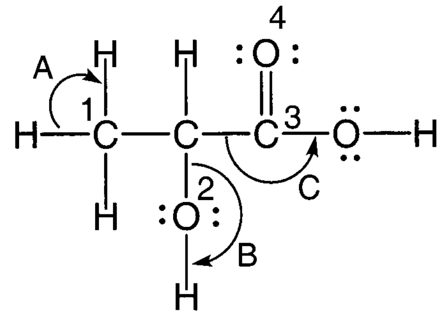
the σ is C_{sp} overlap with N_{sp}

the two π bonds result from overlap between the two pure p orbitals on each of the C & N

The lone pair on N is in a sp hybrid orbital. (1)

(3)

8) Lactic acid ($CH_3CHOHCOOH$) is a natural compound found in sour milk.



8 a) How many π bonds occur in lactic acid? How many σ bonds? (2 points)

1 π (1)

11 σ (1)

8 b) Identify the hybridization of each atom labelled 1, 2, 3, and 4 (4 points)

1: sp^3 (1)

2: sp^3 (1)

3: sp^2 (1)

4: sp^2 (1)

8 c) Which CO bond is the shortest in the molecule? Which CO bond is the strongest? (2 points)

C=O shortest (1)

C=O strongest (1)

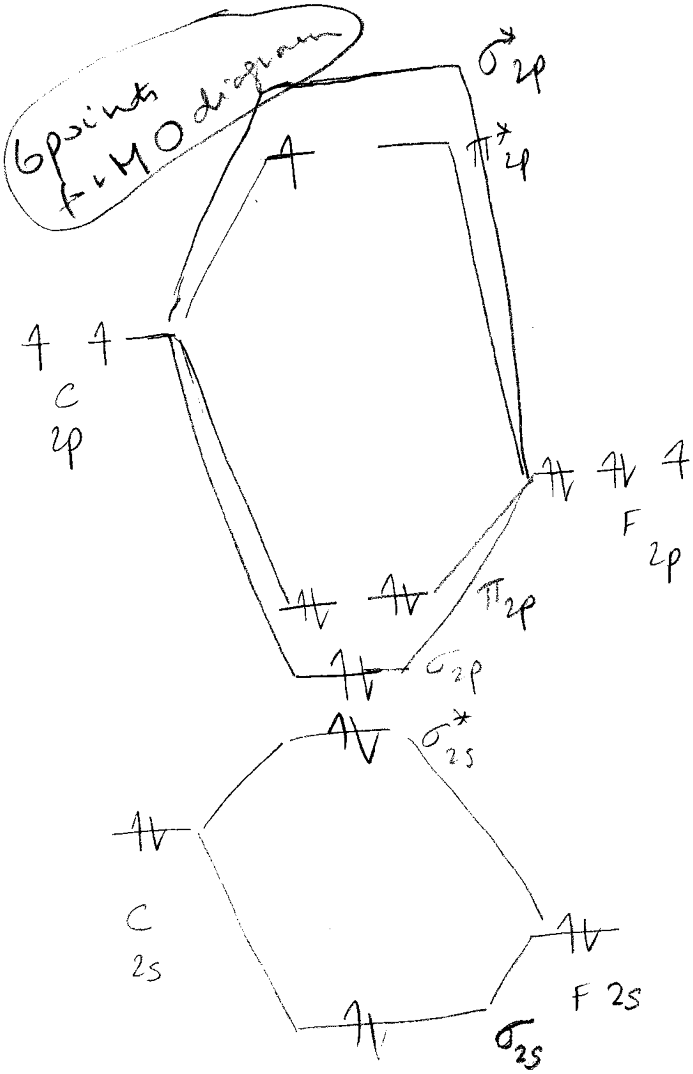
8d) What are the approximate values of the bond angles A through C? (3 points)

A: 109° (1)

B: 109° (1)

C: 120° (1)

9) Use molecular orbital theory to order the following molecules according to increasing C-F bond length: CF, CF^+ and CF^-. Clearly show how you came to your answer. Assume the relative energy ordering of the molecular orbitals follows that of the F_2 molecule. (15 points)



Molecular orbital diagram for CF

Bond order for CF
$= 0.5(8-3) = 2.5$ (2)

CF^+ = remove one electron from π^*_{2p}
Bond order = $0.5(8-2) = 3$ (2

CF^- : add one electron into
Bond order
$= 0.5(8-4) = 2$ (2)

Bond order $CF^- < CF < CF^+$
Smaller bond order, longer bond length] (2)
Order of bond length ; CF^- longest, CF^+ shortest] (
$CF^+ < CF < CF^-$