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Chem 104A - Midterm I Answer Key

closed text, closed notes, no calculators

There are 70 total points. General advice - if you are stumped by one problem, move on to finish other problems and come back later if time permits. You may use the whole class period.

A. General (10 points) 2 Points Each _____

True or false (Enter T or F on line) next to statement:

__F__ **1.** A $4p_z$ orbital has two radial nodes and 2 angular nodes.
It has one angular node – the xy plane.

__F__ **2.** If the principal quantum number is 3, the orbital shape quantum number (l) can be 0, 1, 2, 3, or 4.
The orbital quantum number can only go as high as n-1=l=2; a 3d orbital.

__F__ **3.** The ratio of the ionization energy for He^+ to H is 2:1.
The ionization energy goes as Z^2, thus the ratio is 4:1.

__F__ **4.** The ground state of an atom comes from the term with the lowest multiplicity.
highest multiplicity

__F__ **5.** A proper group always has an identity element and a zero element.
no need for a zero element

B. Configurations & Term Symbols (10 points) 2 Points Each _____

1. Write out the lowest energy electronic **configuration** for elemental V.
You can use [Ar] for the closed inner shells.
$[Ar]4s^2 3d^3$

2. Write out the symbol for the lowest energy **term** (circle the multiplicity):
A term is a collection of levels with the same L and S.
max M_S = 3/2 -> S=3/2; max M_L=2+1+0 = 3 -> L=3 -> 'F'
symbol ^{2S+1}L -> ^4F

3. Write out the complete term symbol for the lowest energy **level** (circle J):
complete term symbol including J: $^{2S+1}L_J$ lowest energy level is min J ;
J = L+S, L+S-1, ..., L-S, thus lowest energy J is 3 – (3/2) = 3/2
$^{2S+1}L_J = {}^4F_{3/2}$

4. What is required to split the degeneracy of the individual **states** ?
electric or magnetic field would do

5. Write out a complete term symbol with the quantum number for any state.
$^{2S+1}L_J$

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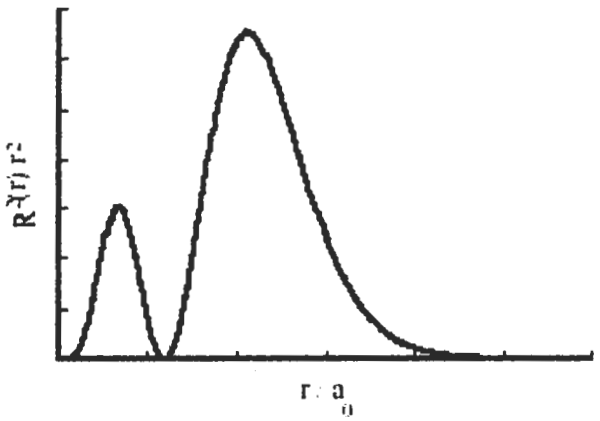
C. Wave Functions (10 points) 2 Points Each _____

Plotted in the graph below is the radial distribution function (electron density function for infinitesimally thin spherical shell of radius r and thickness dr) for a particular orbital ($R^2(r)r^2$).



1. How many radial nodes does this orbital have? ____1____
the origin is not a node

The angular function for the orbital is: $Y = (\text{constant})(x^2 - y^2)$.

2. How many angular nodes does such an orbital have? ____2____

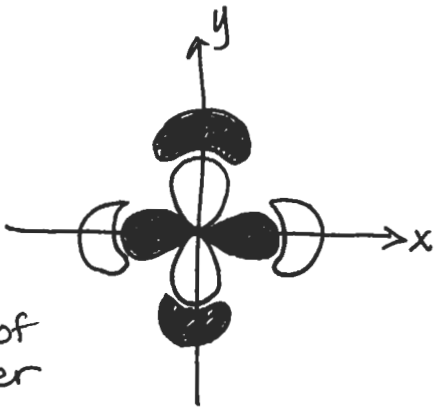
3. What are the equation(s) of the nodal plane(s)?

x=y; x=-y

4. Name the specific orbital that has such a radial and angular electron density distribution:

____$4d_{x^2-y^2}$____

5. Sketch the electron distribution in this orbital.



+Z axis coming out of the paper

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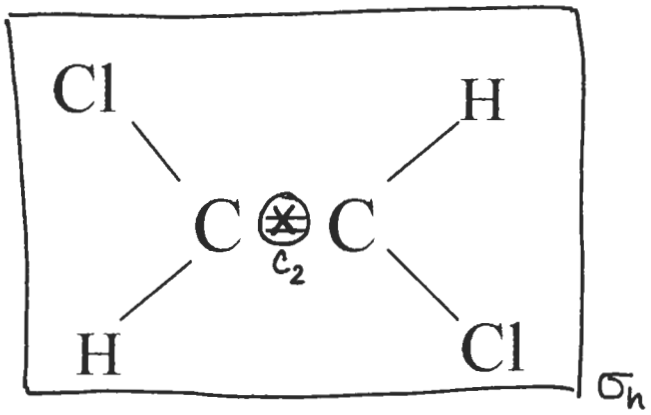
D. Symmetry Points _____

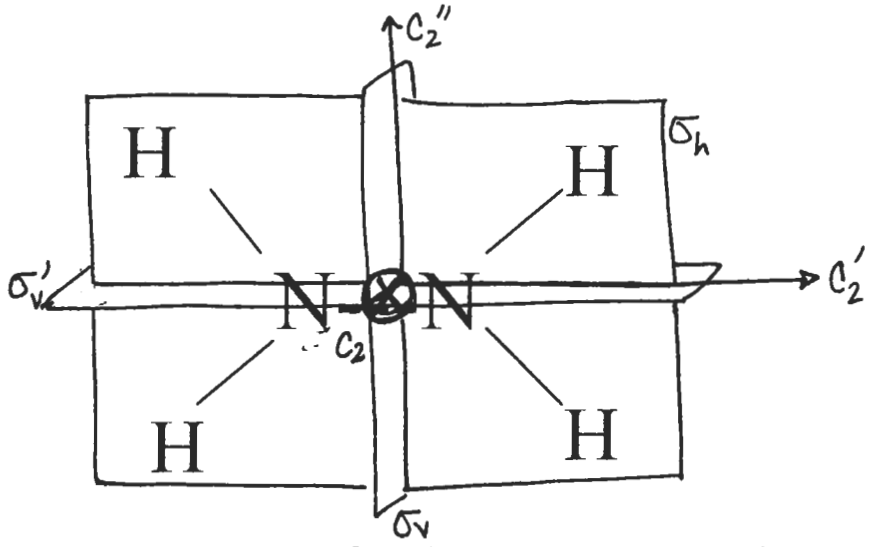
(20 points - 1 for each element) List the symmetry elements present in these molecules. Also, draw lines for any rotation axes that are in the plane of the paper, draw an X for the location of a symmetry axis perpendicular to the plane of the paper. If there are multiple C_n or σ, label additional ones as C_n', C_n'', σ', σ'' *etc.*

1.



1. Symmetry Elements __E___ __C_2___ __σ_h___ __i___

2.



(Eclipsed conformation of hydrazine, all H equivalent)

2. Symmetry Elements E + _ C_2_ _ C_2'_ _ C_2''_ __i__ __σ_h__ __σ_v__ __σ_v'__

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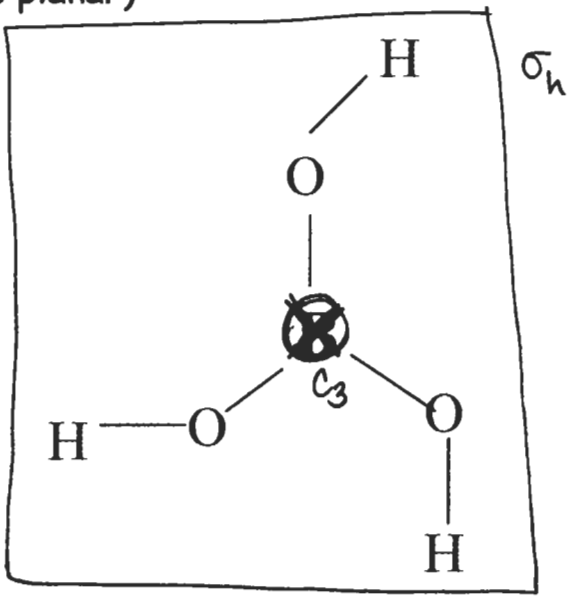
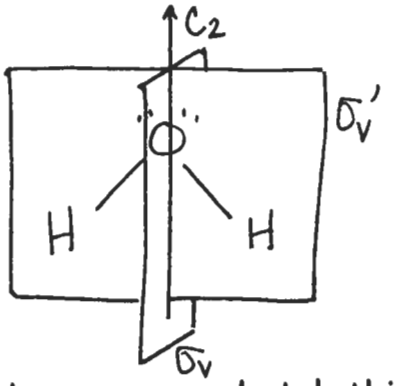
3. (this molecule is planar)



3. Symmetry Elements _E_ _C_3_ _C_3^2_ __σ_h__ _S_3_ _S_3^5_

4.



(Water, you can sketch this one)

4. Symmetry Elements _E__ _ C_2_ __σ_v__ __σ_v'__

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E. Slater's Rules (6 points) 2 Each Points _____

Consider the Na atom (Z=11).

Using Slater's rules shielding coefficients for an electron in energy shell *n*:

0 for electrons in shells greater than *n*,
0.35 for electrons in the same shell,
0.85 for electrons in *n-1* shell
1 for electrons in shells lesser than *n-1*.

1. what is the total shielding coefficient for the Na 3s electron?

Electron configuration: $1s^2 2s^2 2p^6 3s^1$
$\sigma = 2(1) + 8(0.85) = 8.8$

___8.8___

2. what is the effective Z (Z_{eff}) experienced by the 3s electron ?

$Z_{eff} = Z - \sigma$ Z=11
$Z_{eff} = 11 - 8.8 = 2.2$

___2.2___

3. what is the predicted ionization energy in Rydbergs or eV ?

$Na \rightarrow Na^+ + e^-$ $IE = E_{Na+} - E_{Na}$

$E_{electron} = -\frac{Z_{eff}^2}{n^2}(13.6eV)$

$E_{Na+} = 2E_{1s} + 2E_{2s} + 6E_{2p}$
$E_{Na} = 2E_{1s} + 2E_{2s} + 6E_{2p} + E_{3s}$
$IE = -E_{3s} = \frac{Z_{eff}^2}{n^2}(13.6eV) = \frac{2.2^2}{3^2}(13.6eV) = 7.31$ eV

_7.31 eV_

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F. Matching Problems (10 points) 1 points each Points _____

Place letter of phrase on right next to number of person(s) on left that matches best.
Only use each letter once.

1. D	1. Chadwick	a. first measurement of electron's charge
2. F	2. Rutherford	b. proposed wave equation for matter
3. E	3. Stern & Gerlach	c. demonstrated electron diffraction from Ni crystal
4. C	4. Davisson & Germer	d. discovered neutron
5. G	5. Niels Bohr	e. experiments with Ag beams & magnetic field gradient were evidence for electron spin
6. J	6. John Dalton	f. discovered compact nucleus
7. A	7. J. J. Thomson	g. proposed quantized orbits for electrons around nucleus
8. I	8. Louis deBroglie	h. determined atomic numbers from x-ray energies
9. B	9. Erwin Schrödinger	i. first proposed wave-like properties for matter
10. H	10. Henry Moseley	j. revived concept of atom in early 19^{th} century

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G. Suggestion Box (4 points)

1. Which material has been clearest so far (try to find something) ?

2. Which material would you like to go through again (if you had to) ?

Constructive suggestions always welcome here or by e-mail.