

Professor: Don Tilley

Inorganic Chemistry

100 points

Name : \_\_\_\_\_

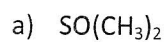
Student ID No.: \_\_\_\_\_

NOTE: THIS IS A CLOSED BOOK EXAM!!

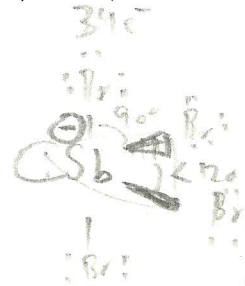
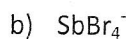
*Looking at other materials or other students' work during the exam period will result in immediate confiscation of your exam, and further disciplinary action.*

<u>Problem</u>		<u>Total Pts</u>
1.	<u>14</u>	(16)
2.	<u>6</u>	(6)
3.	<u>10</u>	(10)
4.	<u>6</u>	(6)
5.	<u>8</u>	(8)
6.	<u>6</u>	(6)
7.	<u>7</u>	(7)
8.	<u>17</u>	(17)
9.	<u>17</u>	(17)
10.	<u>0</u>	(7)
TOTAL	<u>91</u>	(100)

1. For each of the following molecules draw the best Lewis structure, including any formal charges. Be sure to show all valence electrons. Clearly indicate the geometry of each species, according to VSEPR rules and indicate all resonance structures that should be considered (2 pts each; 16 total).



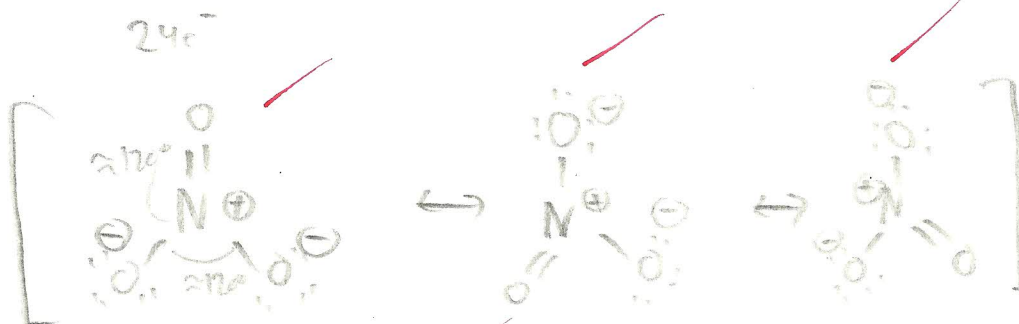
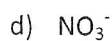
trigonal pyramidal



"See-saw"



Bent



Trigonal Planar

e)  $\text{H}_3\text{CCN}$

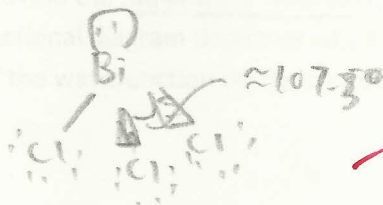


geometry?

-1

f)  $\text{BCl}_3$

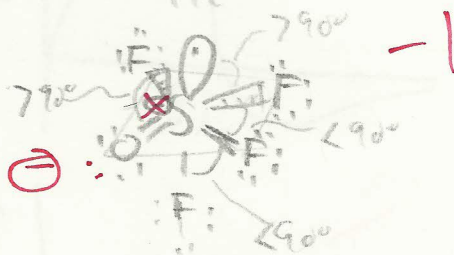
26e<sup>-</sup>



Trigonal pyramidal

g)  $\text{SOF}_4$

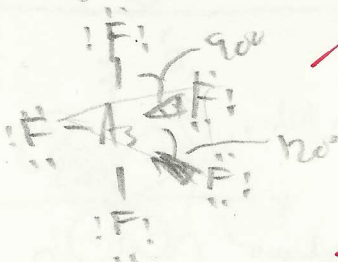
41e<sup>-</sup>



Square pyramidal

h)  $\text{AsF}_5$

40e<sup>-</sup>

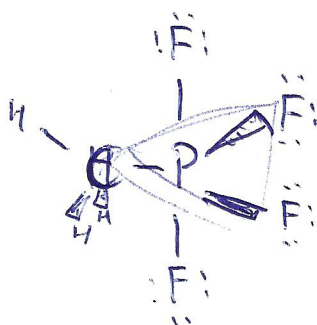


trigonal bipyramidal

2

14  
16

2. Predict the most favored structure for  $\text{P}(\text{CH}_3)_4\text{F}_4$  with a detailed structural drawing in the space below (6 pts).

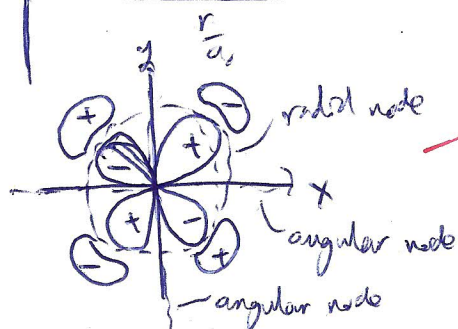
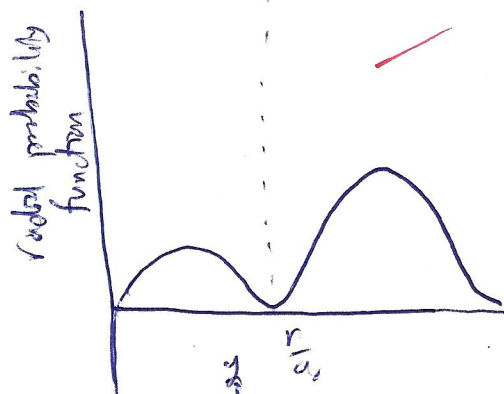
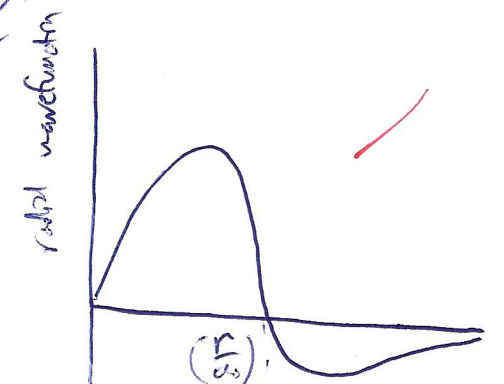


Bent's Rule dictates most electronegative substituent on directed orbitals.

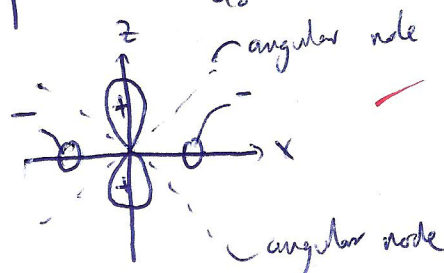
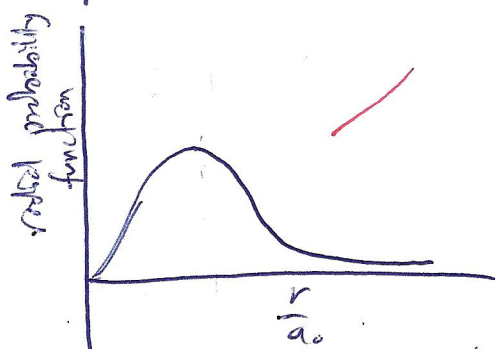
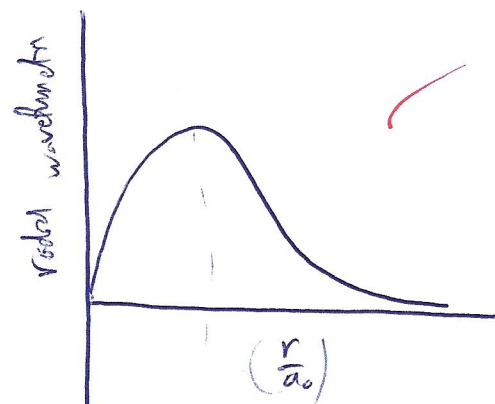
6/6

3. Provide the radial wave functions, radial probability functions, and contour maps of a cross-sectional diagram depicting  $4d_{xy}$  and  $3d_{z^2}$ . Label all axes and indicate positive and negative parts of the wavefunction on the contour map (10 pts).

$4d_{xy}$   
2 angular  
1 radial



$3d_{z^2}$   
2 angular  
0 radial

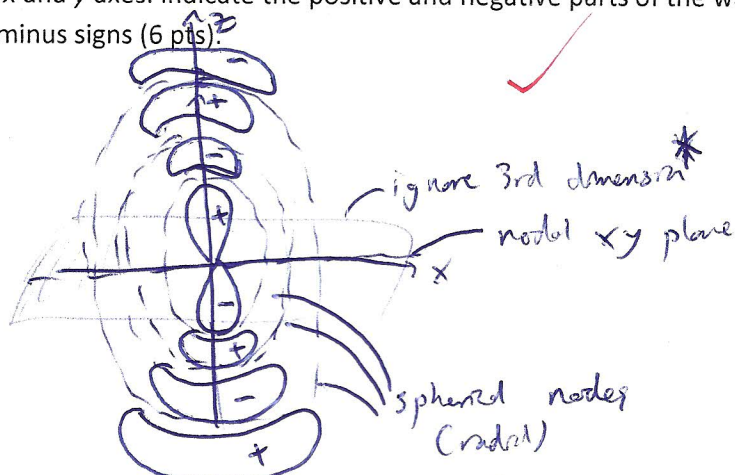


10/10

4. Sketch xy-plane cross-section diagrams for the orbitals listed below. Indicate nodal surfaces by dashed lines. Show the x and y axes. Indicate the positive and negative parts of the wave function with plus and minus signs (6 pts).

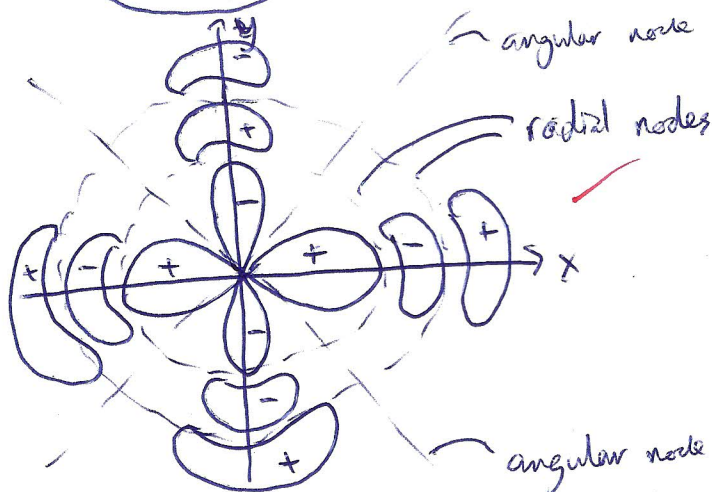
a)  $5p_z$

1 angular node  
3 radial nodes

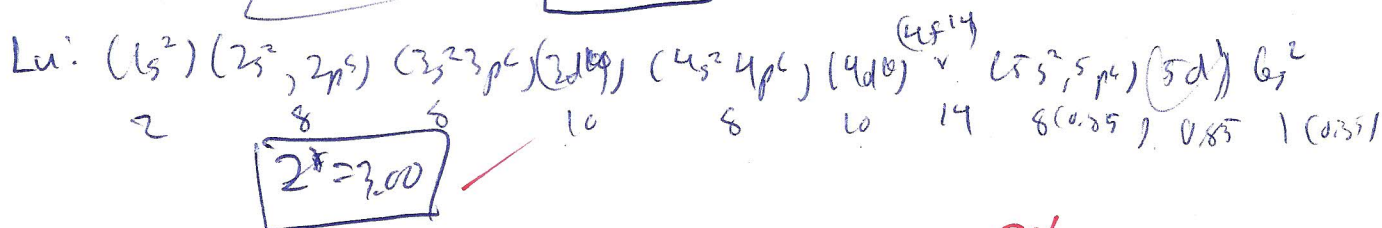
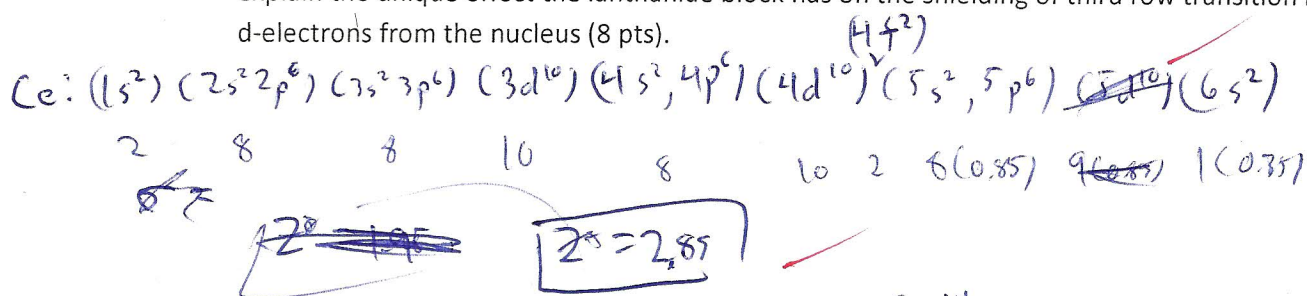


b)  $5d_{x^2-y^2}$

2 angular nodes  
2 radial nodes



5. Calculate the  $Z_{\text{eff}}$  for the outermost electrons in cerium and lutetium. Using these numbers, explain the unique effect the lanthanide block has on the shielding of third row transition metal d-electrons from the nucleus (8 pts).



14f electrons offer poor shielding!

8/8

6/6

$(1.978 = 1.20)$

1.00  
0.65  
1.20  
2.85

1.00  
0.65  
0.70  
2.35

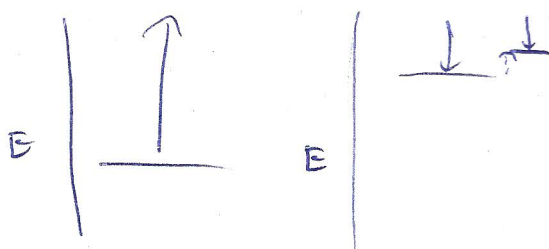
1.00  
0.65  
0.15  
0.20

1.20  
0.65  
0.15  
1.20  
2.00

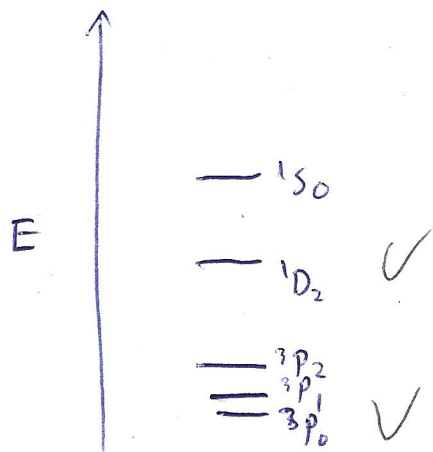


6. Why is the removal of an electron from the -1 charge anion of noble gases and alkaline earth elements exothermic? In general, why are electron affinities smaller in magnitude than the corresponding ionization energies? (6 pts)

- Removal of a -1 charge from noble gas and alkaline earth anions removes an electron alone in a higher orbital (s and p respectively) and ~~decreases~~ <sup>reduces</sup> electron-repulsion, so the process is exothermic.
- Ionization involve removing electrons from a typically lower orbit, Electron affinities also involve adding electron repulsions, making magnitude even smaller.



7. The  $3p^2$  configuration of Si gives rise to the following terms:  $^1S_0$ ,  $^3P_2$ ,  $^3P_1$ ,  $^3P_0$ ,  $^1D_2$ . Use Hund's rules to predict their relative energies, giving explanations for your answer (7 pts).



- 1) Terms with greater spin multiplicity will always be lower in energy so  $^3P_{2,1,0} < ^1D_2, ^1S_0$  ✓

- 2) Next, between terms with same spin multiplicity, the term with greater total orbital angular momentum will be lower  $^1D_2 < ^1S_0$  ✓

- 3) Finally, between terms with same spin multiplicity and L, the terms with lower total angular momentum ( $L+S$ ) for unfilled subshells (for Si, unfilled 3p) will be lower in energy

$$^3P_0 < ^3P_1 < ^3P_2$$

7/7

8. Consider an  $sp^2$  electron configuration (not hybridization).

a) Fill in the top three rows of the microstate table shown below for this electron configuration (12 pts).

$(\frac{5}{2}) = \frac{6 \times 5}{2} = 15$

$2 \uparrow \uparrow -$   
 $1 \uparrow \uparrow -$

		$M_S$			
		$3/2$	$1/2$	$-1/2$	$-3/2$
$M_L$	2		$0^+ 1^+ 1^-$	$0^- 1^+ 1^-$	
	1	$0^+ 1^+ 0^+$	$0^+ 1^+ 0^-$ $0^+ 1^- 0^+$	$0^+ 1^- 0^-$ $0^- 1^+ 0^-$	$0^- 1^- 0^-$
	0	$0^+ 1^+ 1^-$	$0^+ 0^- 0^+ 1^+$ $0^+ 1^+ 0^- 1^-$	$0^- 0^- 0^+ 1^-$ $0^- 1^+ 1^- 0^+ 1^-$	
	-1				
	-2				

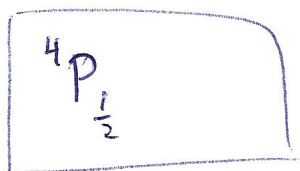
$\frac{0^+ 1^+ 0^+}{\uparrow \uparrow \uparrow}$   
signifies  
 $\frac{0^- 1^+ 0^-}{\uparrow \uparrow \uparrow}$   
signifies  
 $\frac{0^- 1^- 0^-}{\uparrow \uparrow \uparrow}$   
P

$12/12$

b) What is the ground state term for the  $sp^2$  electron configuration (5 pts)?



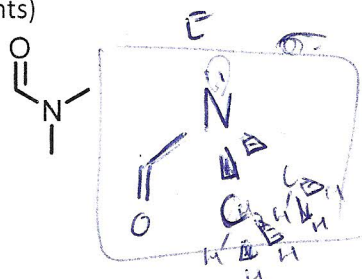
$L = 1$   
 $S = \frac{3}{2}$



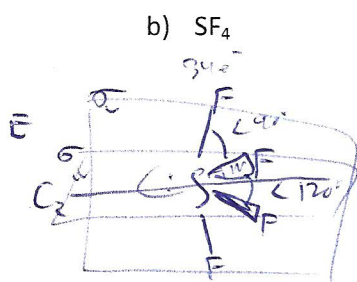
5/5

9. Give the point group of the following molecules. Use the highest symmetry conformation where multiple conformers are possible. For parts a-c, give a molecular representation as well. (17 points)

a)



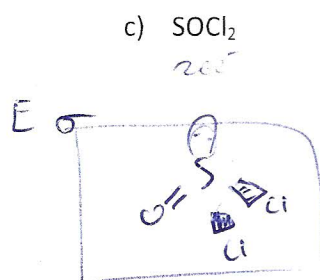
(7/17)



$C_{2v}$



3

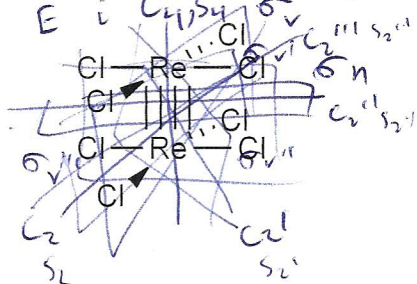


$C_s$



3

d) Treat the Re-Re quadruple bond as cylindrical.

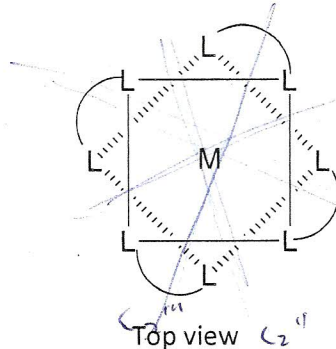


$D_{4h}$

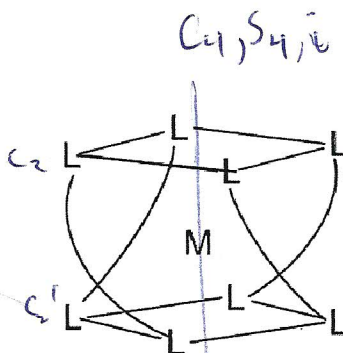


2

e)



Top view  $C_{2v}$



Side view

$D_{4h}$



2





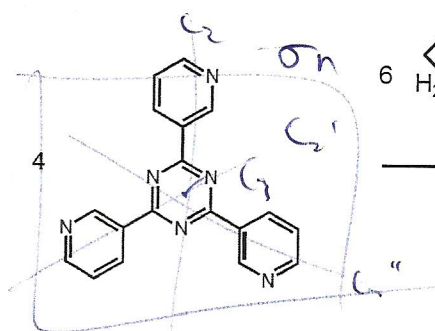
f) For molecules (d) and (e), which (if any) is chiral? Which is polar?

d) achiral, non-polar (i symmetry)

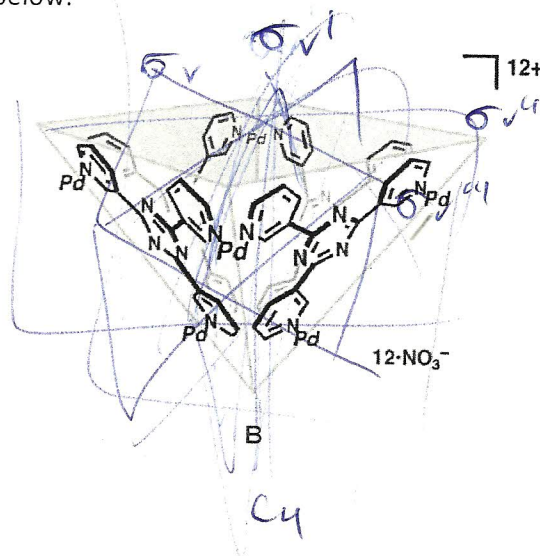
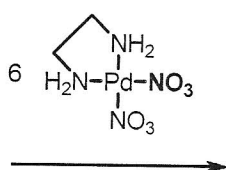
e) chiral (handedness from "jockey"), non-polar (i symmetry)

✓ 4

10. Consider ligand **A** and the metal organic cage **B** shown below.



**A**



**B**

a) What is the point group of **A**? (3 pts)

$D_{3h}$

b) What is the point group of **B** (consider just the cation)? (4 pts)

$O_h$

0/7