THE UNIVERSITY OF BRITISH COLUMBIA

Department of Chemistry

CHEMISTRY 309 - Foundations of Inorganic Chemistry

Mid-term Examination - October 14, 2009

Time: 50 minutes

Other than a model kit, no aids of any kind may be used during the writing of this examination.

A complete examination paper consists of **eight** pages. A blank periodic table of the elements is provided at the end of the examination paper.

Your name: SOLUTIONS

Your student number: _____

Your signature: _____

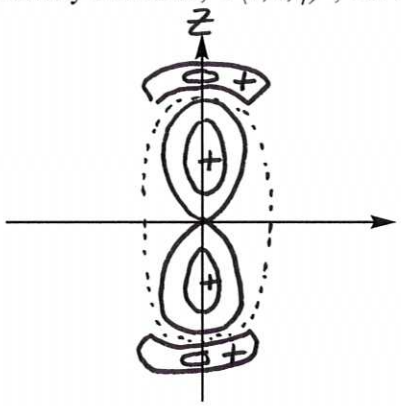
	Mark	Grade
1	35	
2	25	
3	20	
4	20	
Total	100	

1. [35 marks]

On the axes provided sketch the following functions. Be sure to label the axes correctly and to specify the signs of the functions fully.

(a) a contour plot of the probability function, $\Psi(r, \theta, \phi)^2$, for a $3p_z$ orbital

5



dashed line is a node.

(b) the radial function, $R(r)$, for a $4s$ orbital

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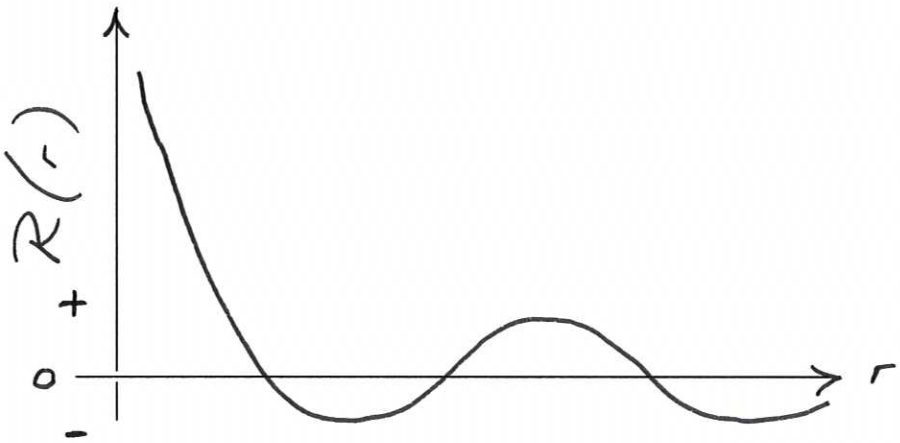
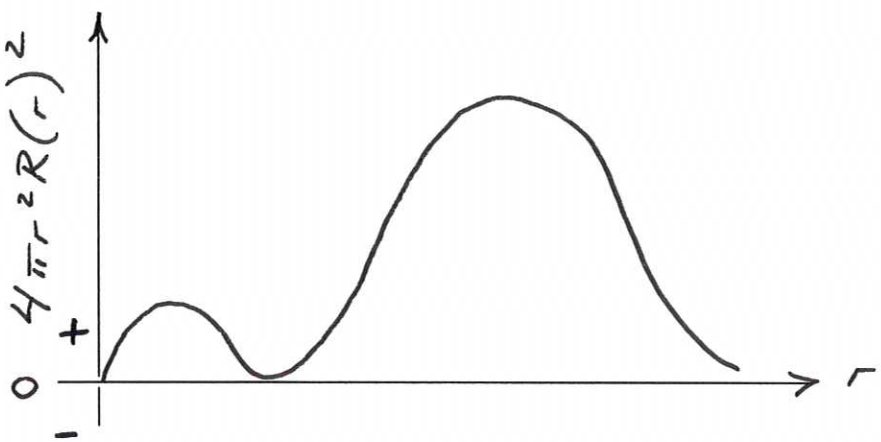


(c) the radial probability function, $4\pi r^2 R(r)^2$, for a $4d_{xy}$ orbital

5



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1. [continued]

(d) the orbital representation of a $5d_{x2-y2}$ wave function, $\Psi(r, \theta, \phi)$.

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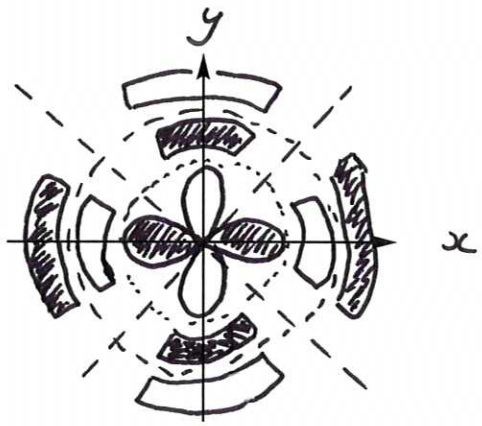

dashed lines are nodes.

(e) the $2s - 2p_x - 2p_y$ hybrid orbital

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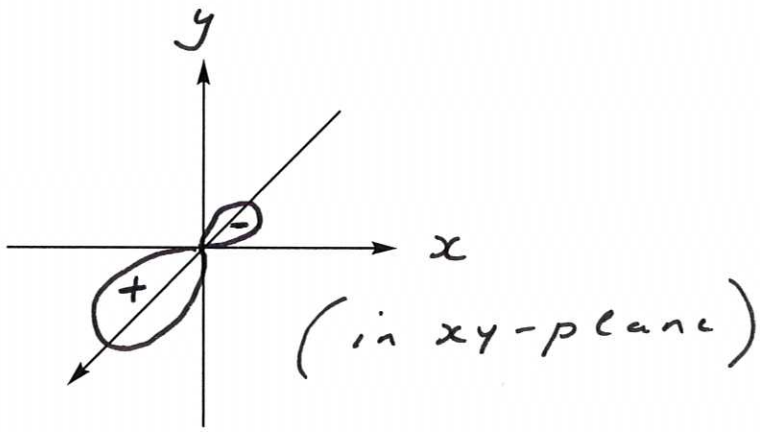

(in xy-plane)

(f) the lowest energy π_u molecular orbital in B_2

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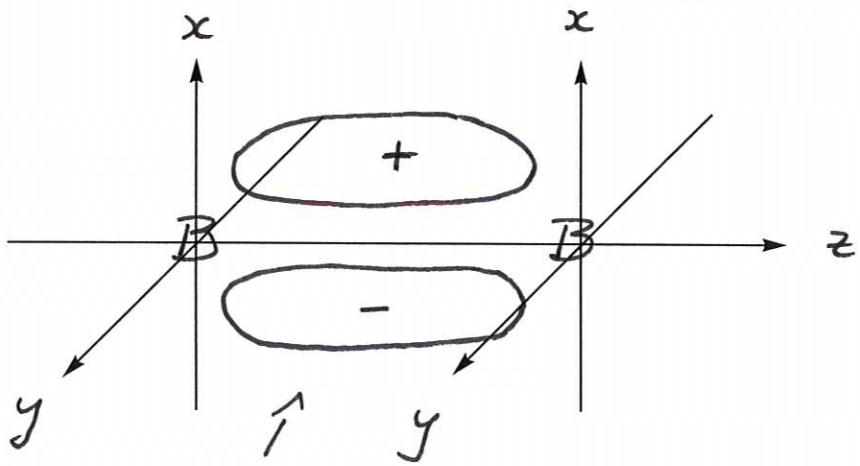


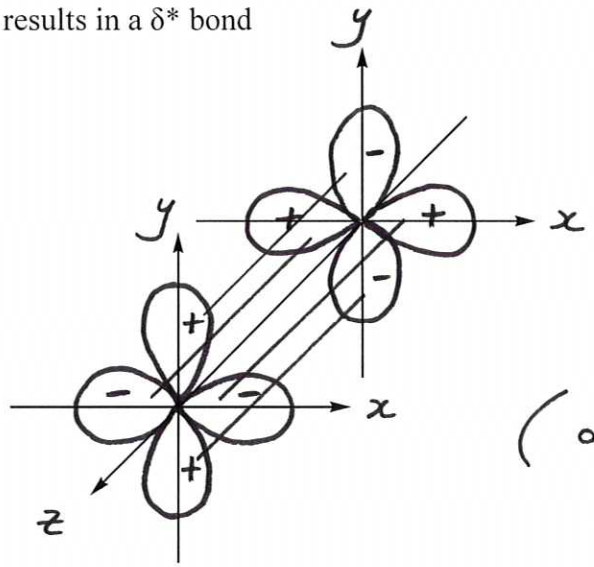
in xz-plane

.....4

(or the one in the yz-plane)

1. [continued]

(g) orbital overlap that results in a δ* bond



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two $d_{x^2-y^2}$ orbitals

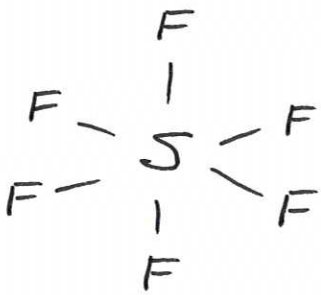
(or two d_{xy} orbitals)

2. [25 marks]

For each of the following molecular entities draw its molecular structure and determine the point group to which it belongs. Indicate also the hybridization at the central atoms and specify which molecules should have a permanent dipole moment.

(a) SF_6

5

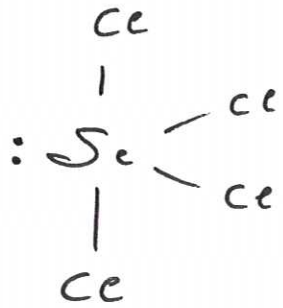


O_h sp^3d^2

no dipole

(b) $SeCl_4$

5



C_{2v} sp^3d

dipole

sawhorse

2. [continued]

(c) $VOBr_3$

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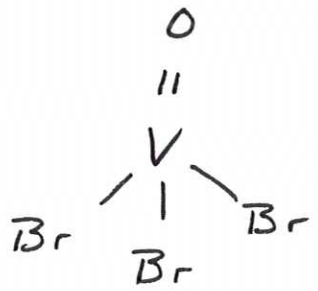


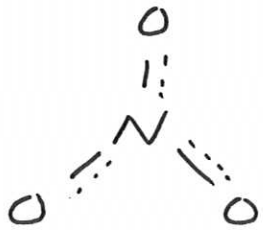
distorted T_d

C_{3v} sp^3

dipole

(d) the nitrate anion

5



$1-$

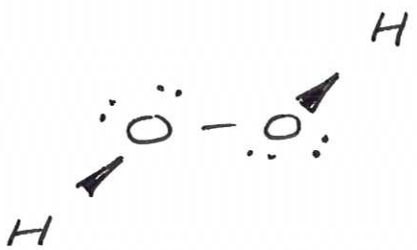
trigonal planar

D_{3h} sp^2

no dipole

(e) hydrogen peroxide

5



twisted structure

C_2

sp^3 at each O

dipole

.....6

3. [20 marks]

A partial character table for the point group D_{2h} is shown below.

D_{2h}	E	$C_2(z)$	$C_2(y)$	$C_2(x)$	i	$\sigma(xy)$	$\sigma(xz)$	$\sigma(yz)$
A_g	1	1	1	1	1	1	1	1
B_{1g}	1	1	-1	-1	1	1	-1	-1
B_{2g}	1	-1	1	-1	1	-1	1	-1
B_{3g}	1	-1	-1	1	1	-1	-1	1
A_u	1	1	1	1	-1	-1	-1	-1
B_{1u}	1	1	-1	-1	-1	-1	1	1
B_{2u}	1	-1	1	-1	-1	1	-1	1
B_{3u}	1	-1	-1	1	-1	1	1	-1

(a) What is the order of this group?

(2) Eight - total number of symmetry operations.

(b) What is its dimension?

(2) Eight - the characters under E.

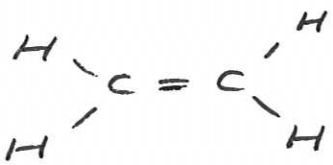
(c) To which representations in this group do the d_{yz} and p_y orbitals belong?

(6) d_{yz} belongs to B_{3g}

(6) p_y belongs to B_{2u}

(d) Which simple hydrocarbon molecule belongs to this point group?

(4) Ethylene



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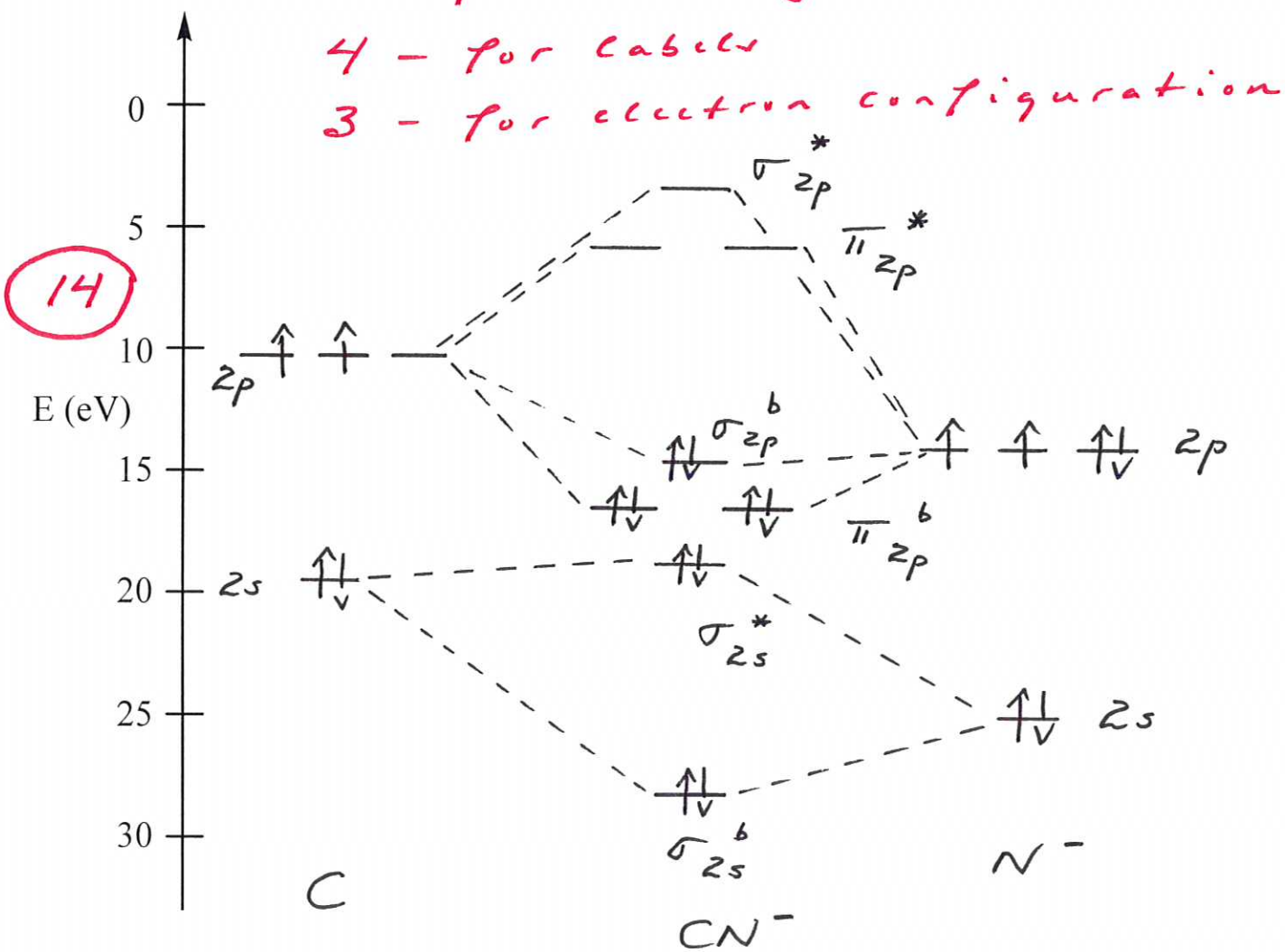
4. [20 marks]

(a) Using the data from the table below, prepare a molecular-orbital energy-level diagram for the cyanide ion, CN^-, showing clearly how the atomic orbitals interact to form molecular orbitals.

Valence-Orbital Ionization Energies (eV)

Atom	1s	2s	2p
H	**13.6**		
He	**24.6**		
Li		**5.4**	
Be		**9.3**	
B		**14.0**	**8.3**
C		**19.4**	**10.6**
N		**25.6**	**13.2**
O		**32.3**	**15.8**
F		**40.2**	**18.6**

7 - for MO diagram
4 - for labels
3 - for electron configuration



4. [continued]

(b) Which is the LUMO for this ion?

3

The degenerate pair of π_{2p}^{*} orbitals.

(c) Which of CN^+, CN, or CN^- would you expect to have the longest bond? Why?

3

Bond order of $CN^+ = 2$

∴ it has the longest C–N bond.

THE END

A blank periodic table of the elements appears on the next page.