THE UNIVERSITY OF BRITISH COLUMBIA

Department of Chemistry

CHEMISTRY 309 - Foundations of Inorganic Chemistry

Mid-term Examination - October 13, 2010

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 **nine** 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	48	
2	40	
3	12	
Total	100	

1. [48 marks]

Indicate the correct answer or answers to each of the following questions, and provide a one-sentence rationale to justify your choices.

(i) Energy is inversely proportional to:

a) wavelength
b) frequency
c) wavenumber
d) Planck's constant
e) none of the above

3

$\Delta E = h\nu$

$= hc/\lambda$

(ii) The MO description of the bonding in $[Ne_2]^{2+}$ indicates that:

a) the ion is paramagnetic
b) the ion has a bond order of zero
c) the ion is likely to be less thermally stable than Ne_2
d) the ion is diamagnetic
e) none of the above

3

$[Ne_2]^{2+}$ – isoelectronic with F_2.

$\sigma_g^2 \pi_u^2 \pi_u^2 \pi_g^{*2} \pi_g^{*2}$ (2p)

(iii) Which of the following molecules does not have T_d symmetry?

a) XeF_4
b) $PbCl_4$
c) P_4
d) $TeCl_4$
e) none of the above

4

XeF_4 is square planar

$TeCl_4$ has sawhorse structure.....3

(iv) Which of the following diatomic molecules are paramagnetic?

a) B_2
b) C_2
c) NO
d) O_2
e) none of the above

4

Explicable by MOT.

(v) How many radial nodes does a 4p atomic orbital possess?

a) 0
b) 1
c) 2
d) 3

3

Radial nodes $= (n - \ell) - 1$
$= (4 - 1) - 1 = 2$

(vi) Which of the following species possess both C_3 and C_2 axes?

a) SO_3
b) SF_6
c) CF_4
d) $[H_3O]^+$
e) none of the above

4

SO_3 is D_{3h}, SF_6 is O_h,
and CF_4 is T_d.

(vii) sp hybridization for the C atom in CO_2 is all that is required to allow for:

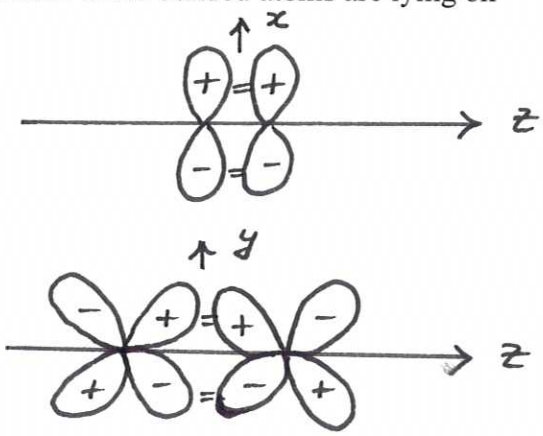
a) the formation of two C=O bonds
b) the formation of the σ component of two double bonds
c) the formation of two σ bonds and two π bonds
d) the formation of a σ bond and accommodation of one lone pair
e) none of the above

3

The π bonds result from $C_{p\pi} - O_{p\pi}$ overlaps.

(viii) Which of the following atomic orbitals can overlap with an atomic orbital of the same type on an adjacent atom to give a π bond if the bonded atoms are lying on the z axis?

a) $2p_x$
b) $3d_{xy}$
c) $3d_{yz}$
d) $3d_z^2$
e) none of the above



3

(ix) The function ψ^2

a) has no physical significance
b) is the probability per unit volume of finding the electron at a particular point
c) is the probability per unit radius of finding the electron at a particular distance from the nucleus
d) is always gerade

3

Postulated.

(x) Which of the following atomic orbitals contains two nodal surfaces?

a) 3s
b) $3p_y$
c) $3d_{z^2}$
d) $3d_{xy}$
e) none of the above

4

From text:
$n-1$ = total # of nodes for any orbital!

3s - 2 radial nodes
3py - 1 radial, 1 angular node
$3d_{z^2}$, $3d_{xy}$ - 2 angular nodes.

(xi) Which of the following elements has the highest first ionization energy?

a) Ra
b) Rh
c) Rb
d) Re

3

(xii) Which of the following elements has the largest electronegativity?

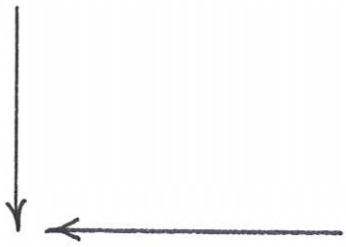
a) P
b) Pt
c) Pd
d) Po

3

(xiii) Which of the following cations has the largest ionic radius?

a) C^{2+}
b) Cd^{2+}
c) Co^{2+}
d) Ca^{2+}

3



(xiv) Which of the following compounds belongs to the point group T_h?

a) WCl_6
b) $W(CO)_6$
c) $W(NMe_2)_6$
d) $[W(en)_3]^{2+}$
e) none of the above

3

The NMe_2 ligands are planar (see Figure 4-13 in text)

(xv) Slater's rules enable one to estimate

a) the electron affinity of an element
b) the electronegativity of an element
c) the first ionization energy of an element
d) the emission line spectrum of an element
e) none of the above

2

2. [40 marks]

The first example of a diamagnetic L(H)BB(H)L compound in which L is a Lewis base was reported three years ago in *J. Am. Chem. Soc.* **2007**, *129*, 12412.

(a) Draw the Lewis dot structure of L(H)BB(H)L.

4

(b) What molecular structures does VSEPR theory predict for L(H)BB(H)L?

4

Planar cis and trans isomers

(as shown above)

(c) To what point groups do these structures belong?

4

C_{2v} C_{2h}

(d) Does the molecule possess a permanent dipole moment?

4

polar non-polar

(e) Provide a VBT rationale of the bonding in L(H)BB(H)L.

4

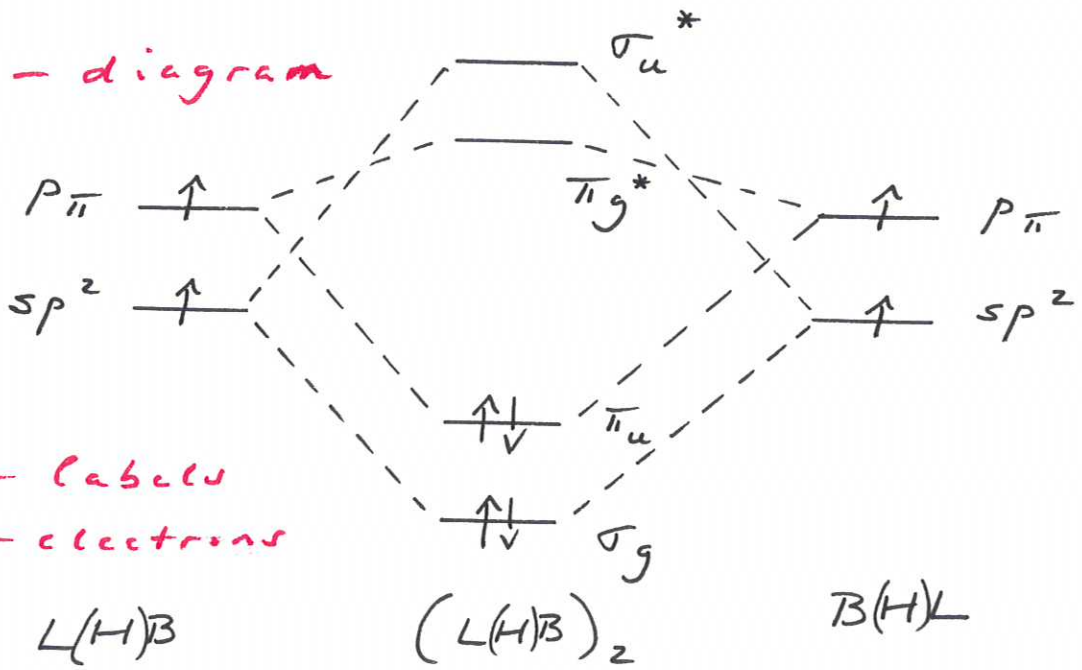
sp^2 hybrids on each B to form σ bonds to the other B, L, and H

A $B\,p_\pi - B\,p_\pi$ interaction completes the B=B double bond.

(f) View the boron compound as dimeric $[L(H)B]_2$ and prepare a molecular-orbital energy-level diagram for the boron-boron bonding in L(H)BB(H)L showing clearly which orbitals interact to form molecular orbitals. Assign symmetry labels to each of the molecular orbitals and indicate their electron occupancies.

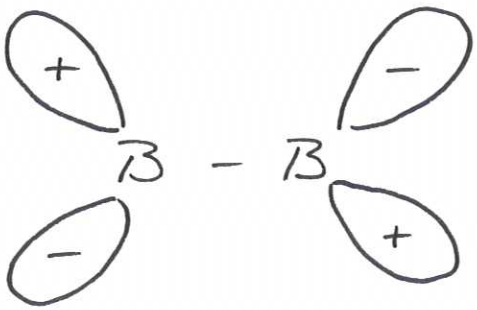
4 – diagram

4 – labels
– electrons



(g) Sketch the LUMO shown in the diagram in part (f).

4



(h) Which would you expect to be more thermally stable, L(H)BB(H)L or $[L(H)BB(H)L]^+$? Why?

4 The neutral compound since it has a B=B linkage. The cation has a B-B bond order of 1.5.

(i) Write a balanced chemical equation for one characteristic reaction that you would expect L(H)BB(H)L molecules to undergo.

4 $L(H)B=B(H)L + Br_2 \longrightarrow L(H)\underset{|}{B}-\underset{|}{B}(H)L$ (Br Br)

3. [12 marks]

Symbols are commonly used in chemistry. For each of the symbols shown below, indicate three things that they symbolize.

3 (a) σ – rotational symmetry, a mirror plane, standard deviation.

3 (b) D – Debye, radial distribution functions, point group designation, (deuterium)

3 (c) H – hydrogen, enthalpy, Hamiltonian operator

3 (d) K – potassium, Kelvin scale, equilibrium constant.

THE END

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