- 1) {2 pts} The general trend in electron affinity is to decrease as you go down the periodic table and <u>Increase</u> as you go right across the periodic table.
- 2) {8 pts} Give the ground-state electron configuration of the following (use core shell notation):
  - [He]2522p2 A. C [Ar] 4s' 3d'0
  - B. Cu
  - C. Nat [Ne]
  - D. Os2+ [xe]5d<sup>6</sup> on [Xe]6s<sup>1</sup>5d<sup>5</sup>
- 3) {4 pts} In general, as you go down the periodic table, atomic size increases . However Hafnium (Hf) is smaller than Zirconium (Zr). What is this effect called and why does it arise? This effect is called the Lanthanide Contraction. The f-block precedes Hf, which have electrons in the 4f orbitals which provide poor shielding and raises the Zeff.
- 4) {4 pts} Circle which of the two has a higher second ionization energy:
  - A. (Be) or Ba B. Cr) or Mn C. (Na) or Mg D. P or (S)
- 5) {9 pts} What is the Mulliken notation (ie the symmetry) of the s, p and d orbitals of the central atom of a molecule which belongs to the D<sub>2d</sub> point group?

$$S = A_1 \qquad dz^2 = A_1$$

$$Px, Py = E \qquad dzx, dyz = E \qquad dxy = B_2$$

$$Pz = B_2 \qquad dx^2 - y^2 = B_1$$

6) {15 pts} Consider the hetronuclear diatomic molecule nitric oxide (NO). Sketch the molecular orbital energy diagram for NO that arises from the atomic orbitals. Be sure to depict [i] the electrons [ii] the relative energy of the orbitals [iii] the anti-bonding orbitals (asterisk them) [iv] the bonding orbitals [v] the starting atomic orbitals and[vi] label the orbitals (s, p, d, σ, π, δ ect...).

$$\frac{N}{2p} \xrightarrow{1} 1 1 \xrightarrow{1} 2p$$

$$2s 1^{1} \xrightarrow{1} 1^{1} \sigma^{*} \xrightarrow{1} 2s$$

A. Is this molecule paramagnetic or diamagnetic?

B. What is the bond order of this molecule?

$$Bo = \frac{1}{2}(b-a) = \frac{1}{2}(8-3) = 2.5$$

C. If one were to remove one electron, making the molecule [NO]<sup>+</sup>, would the bond strength increase or decrease?

- 7) {4 pts} Predict if the following reactions have an equilibrium greater than 1. Assume gas-phase or hydrocarbon solution at 25 °C.
  - A.  $CH_3HgI + HCI \Rightarrow CH_3HgCI + HI \quad K < 1$
  - B.  $AI(CN)_3 + 3Au(OH) \Rightarrow AI(OH)_3 + 3AuCN$  K > 1
- {4 pts} Circle which reactant is acting as a Lewis acid and draw a box around which reactant is acting as a Lewis base.

A. 
$$(SnCl_2) + (Cl^{-} \rightarrow SnCl_3^{-})$$
  
B.  $2SnCl_3^{-} + (Mn_2(CO)_{10}) \rightarrow 2[Mn(SnCl_3)(CO)_5]$ 

9) {15 pts} Consider the molecule IF<sub>3</sub>O<sub>2</sub> (with I as the central atom). At cold temperatures, this molecule cannot go under Berry pseudorotation. Using VSEPR draw all the possible isomers.



- A. Assign point group designations to each isomer.
- B. Which is the most stable isomer? Explain your choice.

- 10) Imagine taking compound A, [Ru<sub>3</sub>(CO)<sub>12</sub>], and refluxing it in HCl. After purification, you isolate compound B and you identify the formula to be [RuCl<sub>3</sub>(H<sub>2</sub>O)<sub>3</sub>]•(H<sub>2</sub>O)<sub>2</sub>. You take compound B and reflux it in acetonitrile (CH<sub>3</sub>CN) under reducing conditions to produce compound C, which you identify as *trans*-[RuCl<sub>2</sub>(CH<sub>3</sub>CN)<sub>4</sub>]. You then take this compound and react it with 2, 2 bipyridine (bipy) and form compound D, [Ru(bipy)<sub>3</sub>]Cl<sub>2</sub>.
  - A. {4 pts} What are the oxidation states of ruthenium in compounds A, B, C and D?

$$A=\phi \quad c=D=Q$$
$$B=3$$

B. {6 pts} Draw only the first coordination sphere of compound **B**; make sure to draw all the isomers and label them.



C. {6 pts} Draw the ligands in compounds C and D. Circle the donor atoms.



D. {6 pts} Draw one possible structure (only the first coordination sphere) for compounds C and D. You may abbreviate the ligands (acn for the CH<sub>3</sub>CN and an arc similar to the one you use for ethylenediamine, en, for bipy).



E. {6 pts} If any of the structure you drew for **B**, **C** and **D** have an optical isomer, draw it and its enantiomer. Make sure to label the absolute configurations.



F. {6 pts} Out of the compounds **B**, **C** and **D** which compound(s) can be tetragonally distorted (Jahn-Teller distorted) without changing their point group.

> compound C compound B in mer conformation

BONUS:

A. {4 pts} Draw the structure of  $[Fe_4S_4Cl_4]^{2-}$  and assign its point group.



3. {4 pts} What is the point group of the spirononane shown below?

