EXAM ONE PART ONE

CHM 451 (INORGANIC CHEMISTRY)

DR. MATTSON 20 SEPTEMBER 2012 NAME:

Instructions: This exam has two parts. In Part One, only a pencil and molecular models may be used. When you have completed Part 1, turn it in and obtain Part Two. In Part Two, your data sheet (on the periodic table) and a non-programmable calculator may be used.

Instructions for Part 1: Some multiple choice questions throughout Part 1 have more than one correct answer.

1. (3 pts) Which of the following pairs give(s) the elements in increasing atomic radii? (circle all correct answers)

   A. Na, Mg

   B. S, F

   C. Al, Ga

   D. Ne, He

   E. V, Ti

2. (3 pts) Which of the following series give(s) the elements in increasing first ionization energy? (circle all correct answers)

   A. Na, Mg

   B. S, O

   C. Al, Ga

   D. He, Ne

   E. Ti, V

3. (3 pts) Ionization energy does not show a smooth change across the periodic table. For which pair(s) of electron configurations would we expect the actual ionization energy to differ from the general trend? (circle all correct answers)

   A. d^1, d^2

   B. p^3, p^4

   C. s^1, s^2

   D. s^2, p^1

   E. f^4, f^5

4. (3 pts) Periodic trends are explained by a variety of ways including (circle all correct answers)

   A. effective nuclear charge

   B. atomic radius

   C. the orbital energy diagram

   D. electron configuration

   E. things that go bump in the dark

5. (3 pts) Which of the following series give(s) the elements in increasing electron affinity? (circle all correct answers)

   A. Si, P

   B. F, Cl

   C. Br, Cl

   D. Br, Kr

   E. Mg, Al

6. (1 pt) The chemical reactivity (ease of oxidation) amongst the Group I and II elements: (one answer)

   A. increases from Group I to Group II

   B. decreases within a group with increasing atomic number

   C. is probably smallest for beryllium

   D. is probably largest for lithium

   E. does not follow a trend

7. (2 pts) Write the ground state electron configuration for Co^{+2}. (Ok to use core designation.) Determine the number of unpaired electrons.

8. (5 pts) Which of the following is/are diamagnetic? Show work.

A. Co^{+2}

B. Mg^{+2}

C. O^{-2}

D. Fe^{+2}

E. Ti^{+3}

9. (5 pts) Determine the ABE formula for each of the following:

A. ____ ClF_3

B. ____ SCN^-

C. ____ SO_2

D. ____ SO_3^{2-}

E. ____ IF_2^-

Questions 10 - 14 pertain to the following five molecules listed here along with their geometries:

CH_4 (tetrahedral geometry)

NH_3 (trigonal pyramid geometry)

OH_2 (bent geometry)

CO_2 (linear geometry)

AsF_5 (trigonal bipyramid geometry)

10. (3 pts) Which of the following has/have a C_3 rotation axis? (circle all correct answers)

A. CH_4

B. NH_3

C. OH_2

D. CO_2

E. AsF_5

11. (3 pts) Which of the following has/have a σ_v mirror plane? (circle all correct answers)

A. CH_4

B. NH_3

C. OH_2

D. CO_2

E. AsF_5

12. (3 pts) Which of the following has a σ_h mirror plane? (circle all correct answers)

A. CH_4

B. NH_3

C. OH_2

D. CO_2

E. AsF_5

13. (3 pts) Which of the following has/have perpendicular C_2 rotation axis/axes? (circle all correct answers)

A. CH_4

B. NH_3

C. OH_2

D. CO_2

E. AsF_5

14. (3 pts) Which of the following is correctly matched with its point group? (circle all correct answers)

A. CH_4 T_d

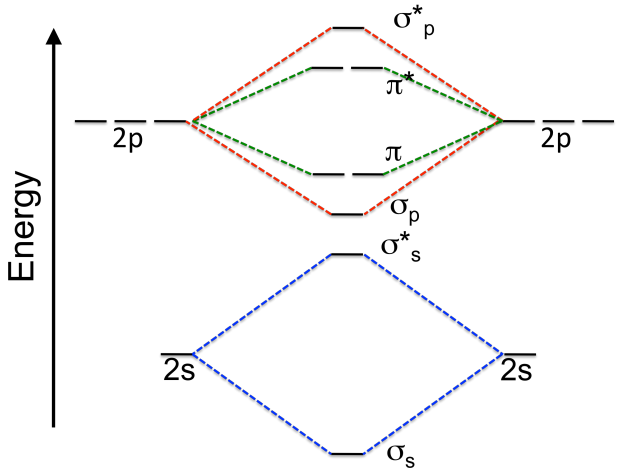
B. NH_3 C_{3v}

C. OH_2 C_{2v}

D. CO_2 $C_{inf\text{-}v}$

E. AsF_5 D_{3h}

15a. (3 pts) Populate this MO diagram for the superoxide ion, O_2^-.



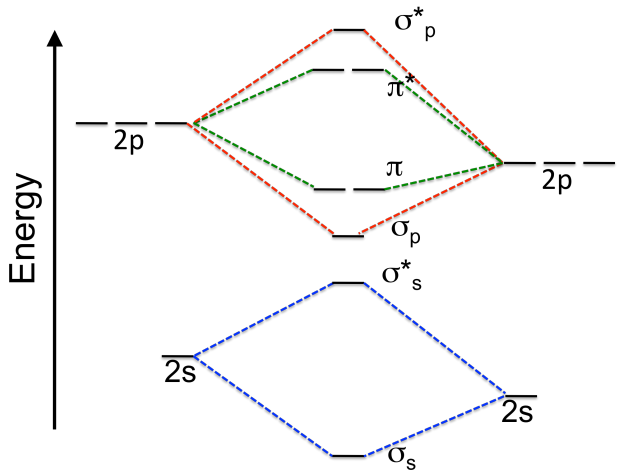
15b. (1 pt) How many unpaired electrons are there?

15c. (1 pt) Determine the bond order.

15d. (1 pt) Would a sample of potassium superoxide be drawn to a neodymium magnet?

15e. (1 pt) Would the oxygen-oxygen bond in superoxide be stronger than in molecular oxygen?

16a. (3 pts) One of the first carbon-containing molecules detected in deep space is the cyano radical, CN. Populate this MO diagram. Make sure you correctly assign the atomic orbitals to either C or N.



16b. (1 pt) How many unpaired electrons are there?

16c. (1 pt) Is the unpaired electron in an orbital that is more C-like or N-like?

17. (3 pts) We saw in a demonstration that laughing gas, N_2O, supports combustion using a candle on a stick. Write and balance the reaction that takes place between dinitrogen monoxide and methane, given that the nitrogen-containing product is $N_2(g)$.

EXAM ONE PART TWO

CHM 451 (INORGANIC CHEMISTRY)

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Instructions for Part 2: Show all work or provide complete explanations! You will receive credit for how you worked each problem as well as for the correct answer. Non-programmable calculators only are allowed during the exam. Illegible handwriting will not be graded. BOX YOUR ANSWERS!

18. Sketch the Lewis dot structure for

18a. (3 pts) sulfur trioxide

18b. (3 pts) nitrogen dioxide

18c. (3 pts) the sulfate ion

19. Determine the effective nuclear charge according to Slater's rules for a

19a. (3 pts) a 2p electron on sulfur

19b. (3 pts) a 3d electron on nickel.

19c. (3 pts) a 3d electron on Mn^{+2}.

20. (8 pts) Predict the state of matter at room temperature for these compounds

AgCl MM = 143.3 g/mol
$GeBr_4$ MM = 392 g/mol
PBr_3 MM = 271 g/mol
IBr MM = 206.8 g/mol
NH_3 MM = 17 g/mol
PF_5 MM = 126 g/mol
CCl_3OH MM = 135.5 g/mol
MgO MM = 40.3 g/mol

21. (16 pts) In Ozone, O_3, has a central atom, O (it is **not** shaped like an equilateral triangle). Create a MO diagram for ozone. Populate the diagram and provide sketches of the bonding molecular orbitals. Provide symmetry labels for each molecular orbital. You may assume that sp-mixing is not important.

What is the bond order?

Would O_3^+ have a larger or smaller bond order than ozone?

Answers:

1. C, E

2. A, B, E

3. B, D

4. A, C, D

5. B, C, E

6. C

7. [Ar] $4s^0 3d^7$

8. B, C

9. A. AB_3E_2

   B. AB_2

   C. AB_2E

   D. AB_3E

   E. AB_2E_3

10. A, B, E

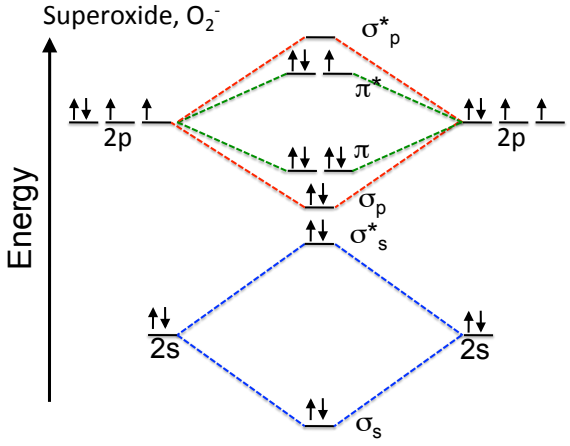
11. all five

12. D, E

13. D, E

14. A, B, C, E

15a.



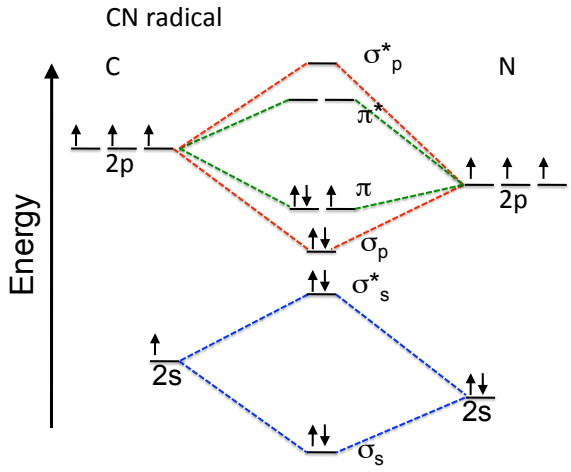
15b. one

15c. bond order = 1.5

15d. yes

15e. it is weaker

16a.



16b. one

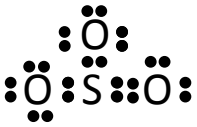
16c. N-like

17. 4 $N_2O(g)$ + $CH_4(g)$ →

4 $N_2(g)$ + 2 $H_2O(g)$ + $CO_2(g)$

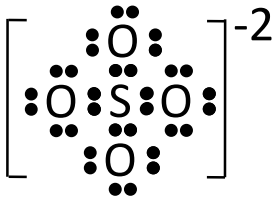
Part 2

18a.



18b.

18c.



19a. 11.85; 19b. 7.55; 19c. 5.6

20. Predict state of matter at RT:

AgCl Ionic → solid

$GeBr_4$ MM > 300 → solid

PBr_3 AB_3E → polar + hi MM → solid

IBr polar, MM ~ 200 → liquid

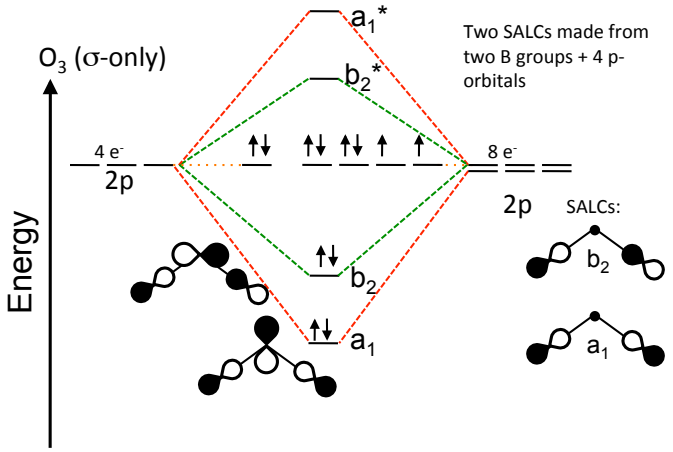
NH_3 partial H-bonding (AB_3E), MM << 100 → gas

PF_5 non-polar AB_5, MM 126 → gas

CCl_3OH H-bonding, MM 136 → liquid

MgO ionic solid

21. Note: The s-orbitals can be ignored because they do not sp mix and they are full of electrons.



This is the grading rubric I used to grade this question:

I will only look for σ-bonding between a central atom and two B groups. Adding the π-manifold was a Day 9 activity and will not be graded.

1. Orbitals of the central atom, O_A, have the same energy as the SALC orbitals because the O_B groups forming the SALCs are also oxygen atoms.

2. The question stated that sp mixing does not occur. This is because the s- and p- orbitals are not close enough in energy to mix. Thus we can eliminate any interaction between the s-orbital on O_A and the SALCs.

3. SALCs should have been created from the p-orbitals on the O_B atoms. Is there a picture of the orbitals used to create SALCs, such as either of these? (Step 1 of the 10-step approach)

4. Step 2. Did you determine the symmetry, C_{2v}?

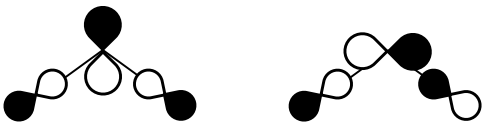
5. Step 3. Did you determine the reducible representation, Γ?

6. Step 4. Did you determine the irreducible components of, Γ, a_1 and either b_1 (if your three atoms are in the xz plane or b_2 if you are using the yz plane as the plane of your atoms)?

7. Steps 6/7. Did you create an MO diagram based on overlap between the p_z orbital (which transforms as a_1) on the central atom, O_A, and $SALC_{a_1}$?

8. Steps 6/7. Does your diagram also include overlap between the p_y orbital (which transforms as b_2) on the central atom, O_A, and $SALC_{b_2}$? (Or the p_x orbital (which transforms as b_1) on the central atom, O_A, and $SALC_{b_1}$?

9. Step 8. Did you include sketches of the bonding MOs? They should look like:



10. Do the number of MOs equal the number of AOs?

11. Did you use the correct number of electrons to populate the MOs? If you showed all the orbitals, there would be 18. If you did not include the s-orbitals, there would be 12, etc.

12. Did you include dashed lines connecting appropriate AOs/SALCs with MOs?

The bond order = 1

O_3 vs O_3^+: Nothing would happen to the bond order considering only the σ-manifold.