Inorganic Exam 1   **Name:**
Chm 451
23 September 2008

1. (5 pts) Periodic trends multiple choice. Each question has only one correct answer.

   (a) Which element of these has the largest first ionization energy?
   A. Ga   B. Ge   C. As
   D. In   E. Sn   F. Sb

   (b) Which element of these has the largest atomic radius?
   A. Ga   B. Ge   C. As
   D. In   E. Sn   F. Sb

   (c) Which element of these has the most metallic character?
   A. Ga   B. Ge   C. As
   D. In   E. Sn   F. Sb

   (d) Which element of these has the largest electron affinity?
   A. Ga   B. Ge   C. As
   D. In   E. Sn   F. Sb

2. (3 pts) Plot the relative first ionization energies for the elements aluminum through argon. Label the x-axis with tick marks for Al, Si, P, S, Cl and Ar. Be careful to include the jog(s) that occur.

3. (3 pts) Plot the relative energies of the first five subsequent ionization energies for scandium.

4. (3 pts) What is the reason why the effective nuclear charge increases from left to right across the periodic table? Be succinct!

5. (3 pts) We saw how potassium was more reactive towards water than was sodium and both were more reactive than lithium. Why was this so?

6. (6 pts) Calculate the Slater shielding, S, for

    (a) S

    (b) a 3d electron on V

7. (3 pts) Describe how Z_{eff} for Ca^{+2} compares to that for elemental calcium?

8. (12 pts) Sketch the Lewis dots structures and determine the ABE formulas for the following species.

$AsCl_3$	BrF_2^+	SiH_3^-
PCl_4^+	PF_6^-	NO_3^-

9. (3 pts) In PCl_3O, phosphorus is the central atom and the other four atoms are bonded to it. Predict the approximate Cl-P-Cl angle.

10. (4 pts) What geometries go with each of these ABE formulas?

AB_3E	AB_2E
AB_4E_2	AB_6

11. (5 pts) Circle each of the following compounds that is expected to be polar:

       $SiCl_4$ NF_3 SH_2 OCl_2 ClO_2

12. (3 pts) The fluorine equivalent to the chlorite ion, ClO_2^- is not known. That is, FO_2^- does not exist. Use Lewis dots, formal charges and resonance to rationalize why the fluorite anion is not known.

13. (5 pts) Which of the following known species is/are paramagnetic? Circle all that are.

NO_2 $\qquad$ ClO_2 $\qquad$ OCl_2 $\qquad$ $C(C_6H_5)_3$ $\qquad$ NO_3
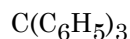
14. (3 pts) BF_3 manages to stay monomeric while BH_3 exists as the dimer B_2H_6. BF_3 does this by achieving an octet within each monomeric unit. Sketch what happens.

15. (10 pts) Classify each substance as ionic, metallic, network covalent or covalent molecular. Predict the state of matter, solid, liquid, gas.

NH_4Cl
C (diamond)
brass
HCl
PCl_5

16. (12 pts)) Complete the following table:

	Primary rotation axis (e.g. C_2)	List other rotation axes (e.g. C_2)	σ_h mirror plane?	How many σ_v mirror planes?	Inversion center?
BF_3 (AB_3)			Yes No		Yes No
NF_3 (AB_3E)			Yes No		Yes No
OH_2 (AB_3E_2)			Yes No		Yes No
CO_2 (AB_2)			Yes No		Yes No

17. (7 pts) Matching. Match the geometry of the compound with its point group.

_____	BF$_3$ (AB$_3$)	A. D$_{4h}$
_____	NF$_3$ (AB$_3$E)	B. C$_{2v}$
_____	OH$_2$ (AB$_3$E$_2$)	C. O$_h$
_____	CO$_2$ (AB$_2$)	D. C$_{3v}$
_____	SF$_6$ (AB$_6$)	E. D$_{3h}$
_____	CH$_4$ (AB$_4$)	F. D∞_h
_____	XeF$_4$ (AB$_4$E$_2$)	G. T$_d$

18. (a) (5 pts) Prepare a molecular orbital energy diagram for NO. The atomic orbitals for N are somewhat higher than those for O. We can ignore s-p mixing. The energies of the N and O s-orbitals are similar enough so that they interact, as do the three p-orbitals on N and O.

(b) (2 pts) Predict the NO bond order.

(c) (1 pts) How many unpaired electrons are present?

(d) (1 pts) Is/are the unpaired electrons in a N-like MO or in a O-like MO?

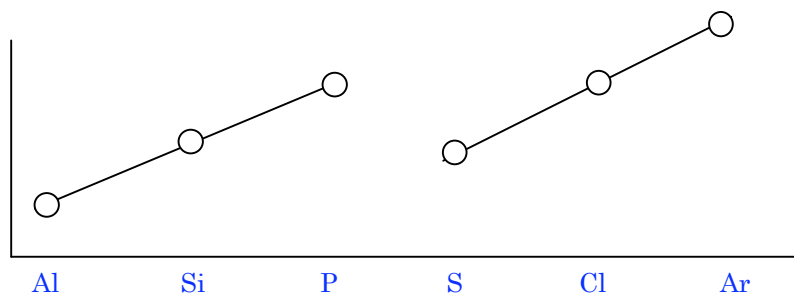(e) (2 pts) What is the bond order for each of the related species:
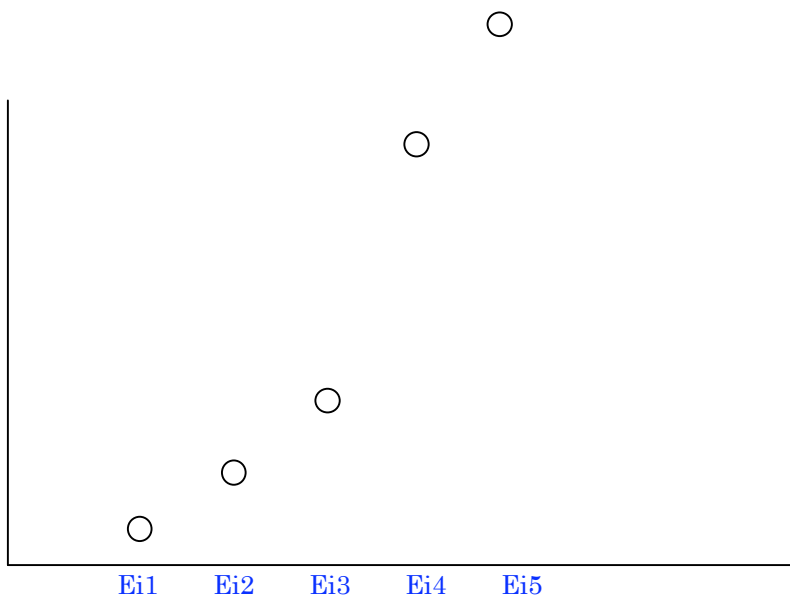
(i) NO$^+$

(ii) NO$^-$

Answers:

1. (a) C, (b) D, (c) D, (d) B or C

2.

Al   Si   P   S   Cl   Ar

3.

Ei1   Ei2   Ei3   Ei4   Ei5

4. The number of protons is increasing by one from one atom to the next, while the shielding provided by the additional electron is only 0.35. typically. Thus, in going from one type of atom to the next larger atom, the effective nuclear charge increases by 0.65.

5. Potassium's valence electron is the 4s which is higher in energy than sodium's 3s and lithium's 2s. Thus, it is easier to oxidize potassium than it is sodium. Overall, ease of oxidation is K > Na > Li.

6. (a) sulfur: S: $(1s)^2 (2s2p)^8 (3s3p)^6$ $S = 5 \times 0.35 + 8 \times 0.85 + 2 \times 1 = 10.55$

   (b) a 3d electron on vanadium: $(1s)^2 (2s2p)^8 (3s3p)^8 (3d)^3 (4s4p)^2$ $S = 2 \times 0.35 + 18 \times 1 = 18.70$

7. Ca^{+2} has two fewer electrons than has Ca to contribute to shielding. Thus Z_{eff} greater for Ca^{+2}

8.

$AsCl_3$ AB_3 E	BrF_2^+ AB_2E_2	SiH_3^- AB_3E
PCl_4^+ AB_4	PF_6^- AB_6	NO_3^- AB_3

9. The Cl-P-Cl angle is predicted to be slightly less than 109 degrees..

10.

AB_3E trigonal pyramid	AB_2E bent
AB_4E_2 square plane	AB_6 octahedron

11. Polar: NF_3 SH_2 OCl_2 ClO_2

12. Without expanding the octet, the formal charge on fluorine is +1. Like all n = 2 elements, fluorine cannot expand its octet.

13. Paramagnetic: NO_2 ClO_2 $C(C_6H_5)_3$ NO_3

14. BF_3 has 3 resonance forms that have B and F double bonded. While this give F a FC of +1, it is spread out over three fluorines, so it isn't as bad. The all single bonded resonance form, with subvalent boron, is also important.

15.

NH_4Cl	ionic	solid
C (diamond)	network covalent	solid
Brass	metallic	solid
HCl	covalent molecular	gas
PCl_5	covalent molecular	liquid due to MM > 200 and non-polar

16. (12 pts)) Complete the following table:

	Primary rotation axis (e.g. C_2)	List other rotation axes (e.g. C_2)	σ_h mirror plane?	How many σ_v mirror planes?	Inversion center?
BF_3 (AB_3)	C_3	C_2	Yes	3	No
NF_3 (AB_3E)	C_3		No	3	No
OH_2 (AB_3E_2)	C_2		No	2	No
CO_2 (AB_2)	C_∞	C_2	Yes	∞	Yes

17. E, D, B, F, C, G, A

18. (b) 2.5; (c) 1;   (d) N-like; (e) (i) 3; (ii) 2