EXAM ONE PART ONE **CHM 451 (INORGANIC CHEMISTRY)**

DR. MATTSON 29 SEPTEMBER 2014 **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), a molecular model set, and a non-programmable calculator may be used.

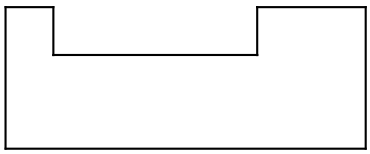
1. (3 pts) Sketch a d-orbital of your own choosing and indicate with dashed lines, the relationship to the Cartesian coordinates, labeled x, y, and z. Label the orbital, for example, d_{xy}.

2. (8 pts) Give the ground state electron configurations for the following. Use "core notation"

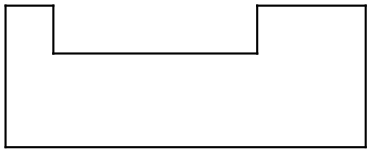
Electron configuration	Unpaired electrons
(a) V	
(b) Cr	
(c) Fe^{+2}	
(d) V^{+3}	

3. (6 pts) Use arrows to indicate the following *general* periodic trends. The pointy part of the arrow should correspond with "increases".

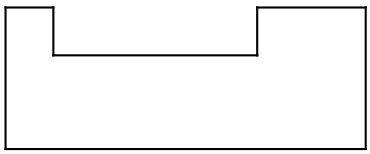
(a) atomic radius



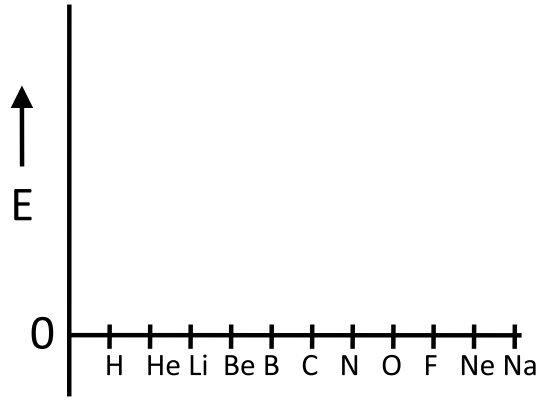
(b) electronegativity



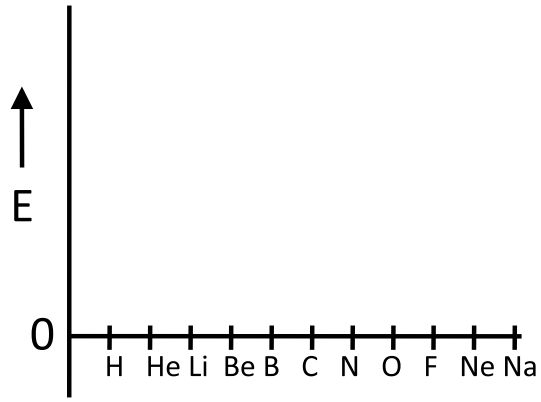
(c) effective nuclear charge



4. (3 pts) Plot the relative first ionization energies for the first 11 elements. Note the x-axis is E = 0.



5. (3 pts) Plot the relative electron affinities for the first 11 elements. Note the x-axis is E = 0.



6. (4 pts) Circle the member of each series with the largest radius.

A. Cr Mo W

B. V Cr Mn

C. S^{-2} Cl^{-} K^{+} Ca^{+2}

D. Mn^{+2} Mn^{+3} Mn^{+4}

7. (1 pt) Which of the following summarizes the definition of electron affinity and what we know about it?

A. $E + e^{-} \rightarrow E^{-}$ $\Delta H \leq 0$

B. $E^{+} + e^{-} \rightarrow E$ $\Delta H \leq 0$

C. $E + e^{-} \rightarrow E^{-}$ $\Delta H \geq 0$

D. $E^{+} + e^{-} \rightarrow E$ $\Delta H \geq 0$

E. $E \rightarrow E^{+} + e^{-}$ $\Delta H \leq 0$

F. $E \rightarrow E^{+} + e^{-}$ $\Delta H \geq 0$

8. (1 pt) Which of the following summarizes the definition of first ionization energies and what we know about it?

A. $E + e^- \rightarrow E^-$ $\Delta H < 0$

B. $E^+ + e^- \rightarrow E$ $\Delta H < 0$

C. $E + e^- \rightarrow E^-$ $\Delta H > 0$

D. $E^+ + e^- \rightarrow E$ $\Delta H > 0$

E. $E \rightarrow E^+ + e^-$ $\Delta H < 0$

F. $E \rightarrow E^+ + e^-$ $\Delta H > 0$

9a. (9 pts) Sketch the Lewis dot structure for the following species in order to answer the questions that follow. Write the ABE formula for each.

SO_3 ABE formula:_____	SF_4 ABE formula:_____
PH_3 ABE formula:_____	ClO_2 ABE formula:_____
XeO_4 ABE formula:_____	SO_2 ABE formula:_____

9b. (6 pts) Based on your work above, complete the table below.

	Geometry name	Paramag-netic?	Polar?
SO_3		Yes No	Yes No
SF_4		Yes No	Yes No
PH_3		Yes No	Yes No
ClO_2		Yes No	Yes No
XeO_4		Yes No	Yes No
SO_2		Yes No	Yes No

10. (2 pts) Fulminates, OCN^-, are notoriously unstable ions, often forming explosive salts. Sketch the an acceptable Lewis dot structure for the fulminate ion (carbon is the central atom) in terms of formal charges. (Assign formal charges.)

11. The following questions 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)

IF_5 (trigonal bipyramid geometry)

11a. (2 pts) Which of the following has/have a C_3 rotation axis/axes? (May be more than one.)

A. CH_4 B. NH_3 C. OH_2

D. CO_2 E. IF_5

11b. (2 pts) Which of the following has/have a σ_v mirror plane/planes? (May be more than one.)

A. CH_4 B. NH_3 C. OH_2

D. CO_2 E. IF_5

11c. (2 pts) Which of the following has a σ_h mirror plane/planes? (May be more than one.)

A. CH_4 B. NH_3 C. OH_2

D. CO_2 E. IF_5

11d. (2 pts) Which of the following has/have perpendicular C_2 rotation axis/axes? (May be more than one.)

A. CH_4 B. NH_3 C. OH_2

D. CO_2 E. IF_5

End of Part 1.

Turn this in and receive Part 2. In Part 2, you can use your data sheet, a molecular model set, and a non-programmable calculator.

EXAM ONE PART TWO

CHM 451 (INORGANIC CHEMISTRY)

DR. MATTSON 29 SEPTEMBER 2014 NAME:

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, your data sheet and a molecular model set are allowed during this portion of the exam. Illegible handwriting will not be graded. BOX YOUR ANSWERS!

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

12a. (2 pts) 3p electron on sulfur

(a)

12b. (2 pts) a 3d electron on cobalt.

(b)

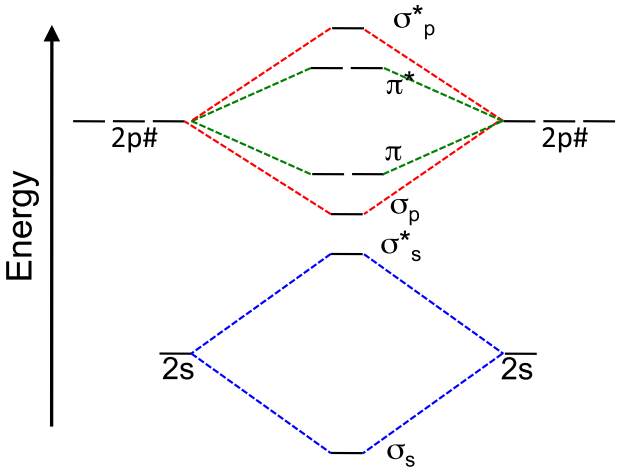
13. (2 pt each) What is the point group for each of these molecules. Choices include: C_1, C_s, C_{2v}, C_{3v}, C_{4v}, C_{5v}, C_{6v}, $C_{\infty v}$, D_{2h}, D_{3h}, D_{4h}, D_{5h}, D_{6h}, $D_{\infty h}$, T_d, O_h, Other

SF_2	SF_4
SF_6	$SClF_5$
BrF	BrF_3

14. (3 pts ea) Consider the following point groups, each followed by four symmetry operations. In each case, circle the ***one*** symmetry operation that does not apply to the point group.

C_{3v}:	C_3	σ_v	σ_h	E
D_{3h}:	C_2	*i*	σ_h	C_3
O_h:	C_2	C_3	C_4	C_5
D_{4h}:	σ_v	*i*	σ_h	S_2

15. Consider this MO diagram to answer the various part of this question.



15a. (3 pt) For which of these molecules could this MO diagram be useful? (Possibly more than one!)

A. O_2 B. N_2 C. HF

D. F_2 E. NO F. CO_2

15b. (1 pt) How many unpaired electrons does superoxide have in the ground state?

15c. (1 pt) What is the bond-order for the peroxide ion?

15d. (4 pts) Sketch the MOs labeled:

σ_s	σ_p^*
π	π^*

16. (3 pts) For which second row diatomic molecules could sp-mixing make a difference between the diatomic molecule being paramagnetic or diamagnetic?

A. Be_2 B. B_2 C. C_2

D. N_2 E. O_2 F. F_2

17. (6 pts) Predict the physical state of the following substances at room temperature (s, l, or g), based on what you know about intermolecular forces, and types of compounds. In some case, narrowing it down to two possible phases (e.g. l or g) is appropriate. Some explanation is required for credit.

SO_3 (MM = 80 g/mol)	CH_2OHCH_2OH (MM = 62 g/mol)
K_2SO_4 (MM = 174 g/mol)	SiH_4 (MM = 32 g/mol)
SF_4 (MM = 108 g/mol)	P_2O_5 (MM = 222 g/mol)

End of Part 2.

Turn this in and you are free to leave. You do NOT have to submit your periodic table.

ANSWERS

1. See text or web

2.

Electron configuration	Unpaired electrons
(a) V [Ar] $4s^2\ 3d^3$	3
(b) Cr [Ar] $4s^1\ 3d^5$	6
(c) Fe^{+2} [Ar] $4s^0\ 3d^6$	4
(d) V^{+3} [Ar] $4s^0\ 3d^2$	2

3. (a) atomic radius: increases going left and going down; (b) electronegativity: increases going right (stopping with the halogens and going up; (c) effective nuclear charge: increases going right and increases going down (but levels off)

4. The general trend for first ionization energies increases across the period from left to right. Some elements have lower 1^{st} IE values because of a singleton electron or one fore than half-filled configurations. The start of a new period is always lower than the element above it. Lithium has a lower 1^{st} IE than H and Na less than Li. For the same reason, Be is less than He. B dips below Be (the $2s^1$ electron is "easier" to remove than the general trend of increasing would predict). Similarly, oxygen is lower due to the configuration involving paired p-electrons: $2p^4$.

5. Filled shells and sub-shells have almost zero electron affinity. Thus, He, Be, and Ne are all zero. Nitrogen with its half-filled sub-shell should have a lower electron affinity as well. As it turns out, it is practically zero as well, even though it is not that low for the rest of the group (P, As, etc.)

6. W, V, S^{-2} Mn^{+2}; 7. A; 8. F

9a.

SO_3 is AB_3	SF_4 is AB_4E
PH_3 is AB_3E	ClO_2 is AB_2E_2
XeO_4 is AB_4	SO_2 is AB_2E

9b.

	Geometry name	Paramag-netic?	Polar?
SO_3	Trigonal plane	No	No
SF_4	See-saw	No	Yes
PH_3	Trigonal pyramid	No	Yes
ClO_2	Bent	Yes	Yes
XeO_4	Tetrahedral	No	No
SO_2	bent	No	Yes

10. Acceptable structures include O single bonded to C, triple-bonded to N, with FC = -1, 0, and 0, respectively, OR O double bonded to C, double-bonded to N, with FC = 0, 0, and -1, respectively. Unacceptable would be O triple bonded to C, single-bonded to N, with FC = +1, 0, and -2, respectively.

11a. A and B; 11b. All of them

11c. D; 11d. A and D

12a. 5.45 ; 12b. 6.90

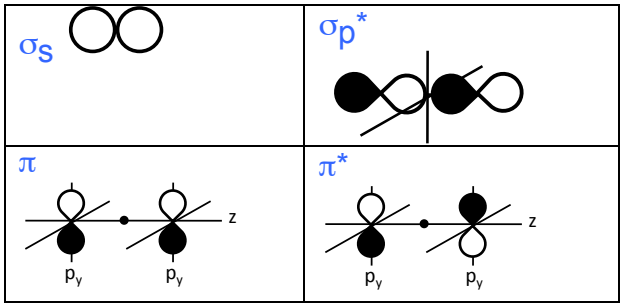
13. (2 pt each) What is the point group for each of these molecules. Choices include: C_1, C_s, C_{2v}, C_{3v}, C_{4v}, C_{5v}, C_{6v}, $C_{\infty v}$, D_{2h}, D_{3h}, D_{4h}, D_{5h}, D_{6h}, $D_{\infty h}$, T_d, O_h, Other

SF_2 is C_{2v}	SF_4 is C_{2v}
SF_6 is O_h	$SClF_5$ is C_{4v}
BrF is $C_{inf\text{-}v}$	BrF_3 is C_{2v}

14. (a) σ_h; (b) *i*; (c) C_5; (d) S_2

15a. A, B, D; 15b. one; 15c. 1

15d. (4 pts) Sketch the MOs labeled:



16. B, C

17.

SO_3 is a gas	CH_2OHCH_2OH is a liquid
K_2SO_4 is a solid	SiH_4 is a gas
SF_4 is predicted to be either a gas or a liquid	P_2O_5 is a solid (although I accepted liquid because you may not know that P_2O_5 is the empirical formula for the molecular P_4O_{10}.