

EXAM INSTRUCTIONS/SUGGESTIONS.  
READ THIS CAREFULLY!

YOU MAY OMIT ANY THREE (3) OF THE FIFTEEN 6 POINT QUESTIONS ON THIS EXAM. IF YOU DO MORE THAN TWELVE OF THEM, ONLY THE FIRST TWELVE WILL BE GRADED. ALL OTHER QUESTIONS MUST BE ANSWERED.

INDICATE ON THE NEXT PAGE WHICH THREE QUESTIONS ARE NOT TO BE GRADED BY WRITING DNG (DO NOT GRADE) NEXT TO PROBLEM NUMBER.

NO PARTIAL CREDIT on any question except where indicated by the statement SHOW WORK. When work is requested, set up equations (with numbers substituted in appropriate units) in space provided, but do the calculations on scrap sheet.

IF THE QUESTION STATES "SHOW WORK" AND YOU GUESS CORRECTLY WITHOUT SHOWING WORK - YOU GET 1/2 CREDIT.

CHECK FRONT BLACKBOARD FOR CORRECTIONS/CHANGES.

DO THE SIMPLER QUESTIONS FIRST.

IF ANY QUESTION IS NOT CLEAR - ASK TANUJA OR ME ABOUT IT!

CONSTANTS AND CONVERSION FACTORS ARE ON THE PAGE AT THE END OF THE EXAM. PLEASE LOOK THERE!  
LAST THREE PAGES ARE FOR SCRAP WORK.  
FEEL FREE TO TEAR THESE PAGES OFF.

FIRST REMINDER: FINAL EXAM ON WEDNESDAY, AUGUST 11<sup>th</sup>  
FROM 9 AM TO 12 NOON.

PLEASE REMOVE THIS SHEET PRIOR TO STARTING EXAM.

CHEMISTRY S1404  
PROFESSOR J. MORROW

SECOND EXAM

7/29/99

PRINT NAME, LAST: \_\_\_\_\_

FIRST: \_\_\_\_\_

I.D.# : \_\_\_\_\_

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MAXIMUM POINT VALUE IS IN PARENTHESIS

- |              |               |              |
|--------------|---------------|--------------|
| 1. _____(6)  | 9. _____(10)  | 17. _____(6) |
| 2. _____(9)  | 10. _____(20) | 18. _____(6) |
| 3. _____(10) | 11. _____(6)  | 19. _____(6) |
| 4. _____(20) | 12. _____(6)  | 20. _____(6) |
| 5. _____(6)  | 13. _____(6)  | 21. _____(6) |
| 6. _____(15) | 14. _____(10) | 22. _____(6) |
| 7. _____(12) | 15. _____(6)  | 23. _____(6) |
| 8. _____(8)  | 16. _____(6)  | 24. _____(6) |

COLUMN TOTALS: (MAXIMUM)

\_\_\_\_\_(86)                      \_\_\_\_\_(70)                      \_\_\_\_\_(48)

EXAM TOTAL (186 pts) \_\_\_\_\_

\_\_\_\_\_  
OUT OF 100

1)

Ionization Energies (kJ/mol)

	Fe	
First		759
Second	1561	
Third		2957
Fourth	_____	4175

A compound, ilmenite, ( $\text{FeTiO}_3$ ) is composed of either  $\text{Fe}^{2+}$  and  $\text{Ti}^{4+}$  ions OR  $\text{Fe}^{3+}$  and  $\text{Ti}^{3+}$  ions. Which combination, ( $\text{Fe}^{2+}$  and  $\text{Ti}^{4+}$ ) or ( $\text{Fe}^{3+}$  and  $\text{Ti}^{3+}$ ) is more reasonable. (6 pts) SHOW WORK

ANSWER IS: \_\_\_\_\_

2) Give the electronic configuration ( $1s^2$  etc) and the number of unpaired electrons (UE) in each of the following gaseous atoms/ions. (9 pts - 3 pts each: 2 pts/1 pt)

Cu UE = $\text{Cu}^+$  UE = $\text{Cu}^{2+}$  UE =

3) An ionic crystalline solid,  $\text{MX}_3$ , has a cubic unit cell. Which of the following arrangements of the ions is consistent with the stoichiometry of the compound? (10 pts)

- i)  $\text{M}^{3+}$  ions at the corners,  $\text{X}^-$  ions at the face centers.
- ii)  $\text{M}^{3+}$  ions at the corners,  $\text{X}^-$  ions at the body center.
- iii)  $\text{X}^-$  ions at the corners,  $\text{M}^{3+}$  ions at the face centers.
- iv)  $\text{X}^-$  ions at the corners,  $\text{M}^{3+}$  ions at the body center.
- v)  $\text{M}^{3+}$  ions at the corners and the body center,  $\text{X}^-$  ions at the face centers.

ANSWER IS: \_\_\_\_\_

- 4) Magnetite,  $\text{Fe}_3\text{O}_4$  ( $231.54 \frac{\text{g}}{\text{mol}}$ ), has a density of  $4.897 \frac{\text{g}}{\text{cm}^3}$ . It is an orthorhombic crystal with  $a = b = 11.86 \text{ \AA}$  and  $c = 16.75 \text{ \AA}$ . How many formula weight units of  $\text{Fe}_3\text{O}_4$  are there per unit cell? How many  $\text{Fe}^{2+}$  ions and how many  $\text{Fe}^{3+}$  ions are there per unit cell? (20 pts) SHOW WORK

The number of formula weight units is:

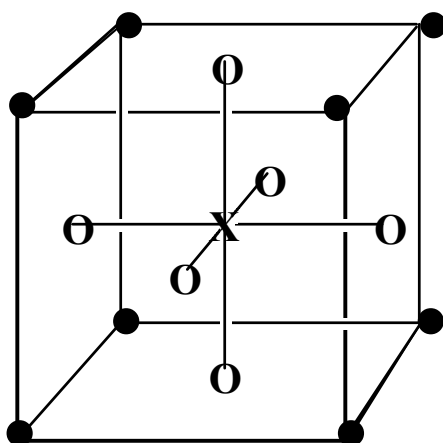
- i) 12      ii) 15      iii) 24      iv) 30      v) 36

# of Formula weights: \_\_\_\_\_

# of  $\text{Fe}^{2+}$  ions: \_\_\_\_\_

# of  $\text{Fe}^{3+}$  ions: \_\_\_\_\_

- 5) Perovskite is a material containing calcium, titanium, and oxygen. The cubic unit cell is shown below.



x =  $\text{Ti}^{4+}$

o =  $\text{O}^{2-}$

● =  $\text{Ca}^{2+}$

Ionic radii:  $\text{Ti}^{4+}$  0.360  $\text{\AA}$ ;  $\text{O}^{2-}$  1.450  $\text{\AA}$

density = 4.759  $\text{g/cm}^3$       Molar mass = 135.96  $\text{g/mol}$

Calculate the unit cell edge length in  $\text{\AA}$ . (6 pts)

ANSWER IS: \_\_\_\_\_

- 6) Osmium is one of the worlds most expensive elements. The abundance of osmium is  $2 \times 10^{-4}$  ppm (parts per million) and it has a melting point of

3045°C. Last year one kilogram of this element sold for 78 *million* dollars. Aside from all of this fascinating information, osmium crystallizes in a face centered cubic lattice. The atomic radius of osmium is 1.352 Å, and its molar mass is  $190.2 \frac{\text{g}}{\text{mol}}$ .

a) Calculate the density of osmium. (10 pts) SHOW WORK

ANSWER IS: \_\_\_\_\_

b) Calculate its molar volume ( $\frac{\text{cm}^3}{\text{mol}}$ ). (5 pts)

ANSWER IS: \_\_\_\_\_

7) Give the hybridization for each underlined atom in the following ions. Also give the actual spatial appearance of the ion. If the ion cannot exist, write CNE, in space provided. (ie.  $sp^2$  / trigonal)  
Group numbers: N (5), Cl (7), S (6), F (7) (12 pts - 3 pts each)

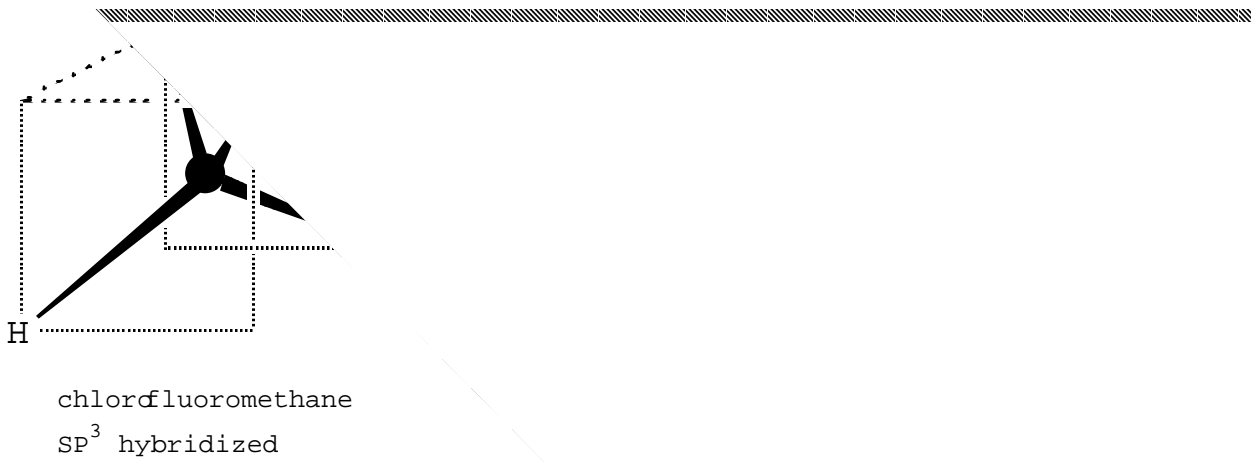
i)  $\underline{\text{I}}\text{F}_4^+$  \_\_\_\_\_ / \_\_\_\_\_

ii)  $\underline{\text{S}}\text{F}_5^+$  \_\_\_\_\_ / \_\_\_\_\_

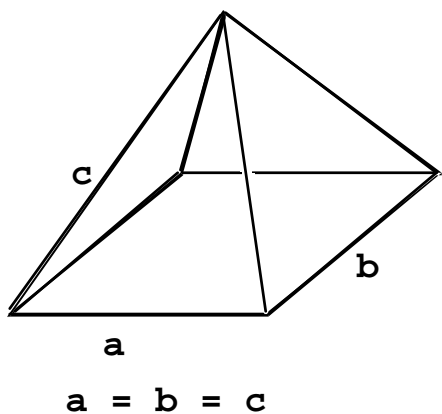
iii)  $\underline{\text{N}}\text{F}_4^-$  \_\_\_\_\_ / \_\_\_\_\_

iv)  $\underline{\text{B}}\text{F}_4^+$  \_\_\_\_\_ / \_\_\_\_\_

- 8) State how many of each of the following types of elements of symmetry exist in chlorofluoromethane. (8 pts)



- 9) State how many of each of the following types of elements of symmetry exist in square based pyramid below. (10 pts)



center of symmetry

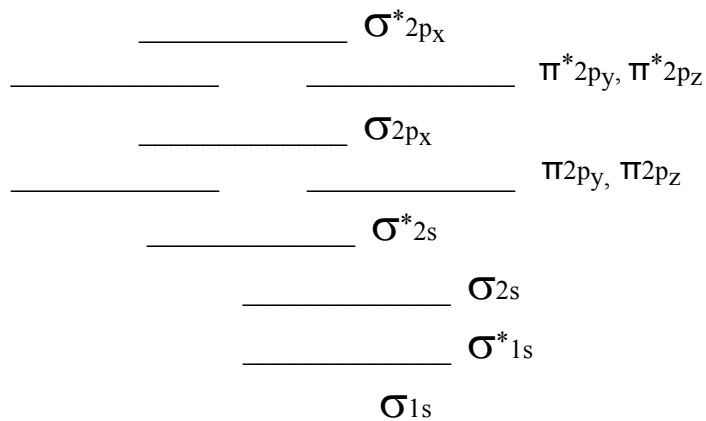
two fold axis of rotation, C<sub>2</sub>

three fold axis of rotation, C<sub>3</sub>

four fold axis of rotation, C<sub>4</sub>

planes of symmetry

Use the MO correlation diagram below (where needed) to answer questions 10, 11, and 12.



- 10) Predict the apparent bond order, relative bond length, and number of unpaired electrons in the following species; CO, BN, and BeC. Where relative values are compared, use  $<$  or  $>$  otherwise use the calculated numerical values. (20 pts)

	CO	BN	BeC
<u>Bond order</u>			
<u>Bond Length</u>			
<u>Bond enthalpy</u>			
<u>Number of unpaired electrons</u>			

- 11) If light of the proper wavelength is used an electron in the  $\pi_{2py}$  molecular orbital is excited to the  $\pi^*_{2py}$ . What is the bond order after this transition in BeC? (6 pts)

bond order =

- 12) List the following in order of increasing bond length:  $\text{Li}_2$ ,  $\text{Ne}_2^+$ , and  $\text{F}_2$ . (6pts)

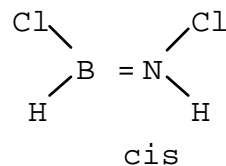
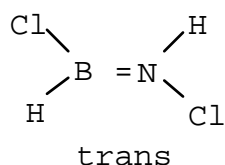
\_\_\_\_\_ < \_\_\_\_\_ < \_\_\_\_\_

- 13) The bond order of each of the following, C-H, O-H, and F-H, is 1. List them in order of decreasing bond enthalpy. (6 pts)

\_\_\_\_\_ > \_\_\_\_\_ > \_\_\_\_\_

14) The molecule  $\text{BNH}_2\text{Cl}_2$  exists in two forms, a cis form and a trans form.

GIVEN: Bond enthalpies (kJ/mol): B=N (511); N-N (163); B-N (212);  
N-H (388); N-Cl (381); B-H (551); Cl-Cl (243); B-Cl (349)



Calculate the energy per molecule,  $\left(\frac{\text{J}}{\text{molecule}}\right)$ , required to convert the trans form to the cis form. (10 pts)

i)  $8.48 \times 10^{-19}$  ii)  $4.97 \times 10^{-19}$  iii)  $3.52 \times 10^{-19}$  iv)  $2.67 \times 10^{-19}$

ANSWER IS: \_\_\_\_\_

THE FOLLOWING PERIODIC TABLE MAY BE OF USE IN ANSWERING THE REMAINING PROBLEMS.

Group Number

	I <sub>A</sub>	II <sub>A</sub>	III <sub>A</sub>	IV <sub>A</sub>	V <sub>A</sub>	VI <sub>A</sub>	VII <sub>A</sub>	Inert gas	
Period	2	Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	
	3	Na 0.97	Mg	Al 1.5	Si	P 2.1	S 2.5	Cl 3.0	
		K 0.90	Ca	Ga	Ge	As	Se 2.4	Br 2.8	
	5	Rb 0.87	Sr	In	Sn	Sb	Te	I 2.5	

Beneath most symbols are electronegativity values. Please use them where necessary in answering this question.

15) List the following atoms in order of decreasing 2<sup>nd</sup> ionization energy: O, S, and K. (6 pts)

\_\_\_\_\_ > \_\_\_\_\_ > \_\_\_\_\_

16) List the following in order of decreasing radius.

$\text{Na}^+$ ,  $\text{Mg}^+$ , and  $\text{K}^+$ . (6 pts)

\_\_\_\_\_ > \_\_\_\_\_ > \_\_\_\_\_

17) List the ions  $S^{2-}$ ,  $P^{3-}$ , and  $N^{3-}$ , in order of increasing ionic radius, that is, the largest is last. (6 pts) \_\_\_\_\_ < \_\_\_\_\_ < \_\_\_\_\_

18) List the following ions in order of decreasing ionic radius.  $Li^+$ ,  $Be^{3+}$ , and  $B^+$  (6 pts) \_\_\_\_\_ > \_\_\_\_\_ > \_\_\_\_\_

19) List the following gases in order of decreasing molecular bond enthalpy  $P_2$ ,  $S_2$ , and  $Cl_2$ . Lowest goes last. (6 pts) \_\_\_\_\_ > \_\_\_\_\_ > \_\_\_\_\_

20) List the following atoms in order of decreasing 3<sup>rd</sup> ionization energy. Li, Na, and Al (6 pts) \_\_\_\_\_ > \_\_\_\_\_ > \_\_\_\_\_

21) Which of these molecules is/are non-polar ;  $IF_3$ ,  $BF_3$ ,  $NF_3$ ,  $SF_4$ ,  $XeF_4$ ? (6 pts)

ANSWER: \_\_\_\_\_

22) Circle the stronger acid in each of the following pairs.

i)  $H_2S_2O_3$  or  $H_2S_4O_6$  (3 pts)

ii)  $HIO_3$  or  $HClO_3$  (3 pts)

23) Match up the following bond enthalpies (in kJ/mol), 163, 360, 412, and 436, , with the indicated molecules; (6 pts)

H-H \_\_\_\_\_ C-H \_\_\_\_\_ C-O \_\_\_\_\_ N-N \_\_\_\_\_

24) In a multi-electron atom, how many electrons can have the following sets of quantum numbers? (6 pts - 2 pts each)

i)  $n = 3$ ,  $m_\lambda = 0$ ,  $m_s = -\frac{1}{2}$  \_\_\_\_\_

ii)  $n = 4$ ,  $m_\lambda = -2$ ,  $m_s = +\frac{1}{2}$  \_\_\_\_\_

iii)  $n = 4$ ,  $m_\lambda = +2$  \_\_\_\_\_

*CONVERSION FACTORS and POTENTIALLY (BUT NOT NECESSARILY)  
USEFUL EQUATIONS*

$$C = 3.00 \times 10^8 \text{ m/sec} = 3.00 \times 10^{10} \text{ cm/sec}$$

$$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{sec} = 6.626 \times 10^{-27} \text{ erg}\cdot\text{sec}$$

$$m_e = 9.108 \times 10^{-28} \text{ g} = 9.108 \times 10^{-31} \text{ kg}$$

$$\mathcal{E} = h\nu$$

$$N_A = 6.022 \times 10^{23}$$

$$R = 0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{degK}} = 82.1 \frac{\text{cm}^3\cdot\text{atm}}{\text{mol}\cdot\text{degK}}$$

$$\lambda\nu = c$$

$$1 \text{ \AA} = 0.1 \text{ nm} = 10^{-8} \text{ cm} = 10^{-10} \text{ m}$$

$$\lambda = \frac{h}{p} \quad (\text{deBroglie equation}) \quad \text{where } p = mv$$

$$\text{Heisenberg Uncertainty principle: } \Delta p \Delta X = \frac{h}{4\pi} \quad \text{where } p = mv$$

$$\text{kinetic energy: } \mathcal{E} = \frac{1}{2} mv^2 = \frac{p^2}{2m} \quad \text{where } p = mv$$

$$q = e = 1.6022 \times 10^{-19} \text{ coulombs} = 4.806 \times 10^{-10} \text{ esu}$$

$$1 \text{ eV} = 1.6022 \times 10^{-19} \text{ J}$$

$$\mathcal{E}_n = - \frac{2.179 \times 10^{-18}}{n^2} \text{ J}$$

$$\mathcal{E} = qV = h\nu - \Phi$$

UNIT RELATIONSHIPS

$$1 \text{ amp} = 1 \frac{\text{coulomb}}{\text{sec}}$$

$$1 \text{ volt}\cdot\text{coulomb} = 1 \text{ Joule}$$

$$1 \text{ esu}^2 = 1 \text{ erg}\cdot\text{cm}$$

$$1 \text{ Watt} = 1 \frac{\text{joule}}{\text{sec}}$$

$$1 \text{ Joule} = 1 \times 10^7 \text{ erg} \quad 1 \text{ Joule} = 1 \frac{\text{kg}\cdot\text{m}^2}{\text{sec}^2} \quad 1 \text{ erg} = 1 \frac{\text{g}\cdot\text{cm}^2}{\text{sec}^2}$$

## SCRAP WORK SHEET

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