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 11th FROM 9 AM TO 12 NOON.

PLEASE REMOVE THIS SHEET PRIOR TO STARTING EXAM.
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**COLUMN TOTALS: (MAXIMUM)**

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**EXAM TOTAL (186 pts)** __________________________ OUT OF 100
1) Ionization Energies (kJ/mol)

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<td>Second</td>
<td>1561</td>
</tr>
<tr>
<td>Third</td>
<td>2957</td>
</tr>
<tr>
<td>Fourth</td>
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A compound, ilmenite, (FeTiO₃) is composed of either Fe²⁺ and Ti⁴⁺ ions OR Fe³⁺ and Ti³⁺ ions. Which combination, (Fe²⁺ and Ti⁴⁺) or (Fe³⁺ and Ti³⁺) is more reasonable. (6 pts) SHOW WORK

ANSWER IS: ________

2) Give the electronic configuration (1s² 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 =
- Cu⁺         UE =
- Cu²⁺        UE =

3) An ionic crystalline solid, MX₃, has a cubic unit cell. Which of the following arrangements of the ions is consistent with the stoichiometry of the compound? (10 pts)

i) M³⁺ ions at the corners, X⁻ ions at the face centers.
ii) M³⁺ ions at the corners, X⁻ ions at the body center.
iii) X⁻ ions at the corners, M³⁺ ions at the face centers.
iv) X⁻ ions at the corners, M³⁺ ions at the body center.
v) M³⁺ ions at the corners and the body center, X⁻ ions at the face centers.

ANSWER IS: ______
4) Magnetite, Fe₃O₄ (231.54 g/mol), has a density of 4.897 g/cm³. It is an orthorhombic crystal with a = b = 11.86 Å and c = 16.75 Å. How many formula weight units of Fe₃O₄ are there per unit cell? How many Fe²⁺ ions and how many Fe³⁺ 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 Fe²⁺ ions: ______
# of Fe³⁺ ions: ______

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

The cubic unit cell is shown below.

\[ \text{Ionic radii: } ^{4+} \text{Ti} \approx 0.360 \text{ Å; } ^{2-} \text{O} \approx 1.450 \text{ Å} \]

 density = 4.759 g/cm³  Molar mass = 135.96 g/mol

Calculate the unit cell edge length in Å. (6 pts)

ANSWER IS: ______

6) Osmium is one of the worlds most expensive elements. The abundance of osmium is 2x10⁻⁴ 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 $\frac{g}{mol}$.

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

ANSWER IS: _______

b) Calculate its molar volume ($\frac{cm^3}{mol}$). (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. sp² / trigonal)
Group numbers: N (5), Cl (7), S (6), F (7) (12 pts - 3 pts each)

i) $\underline{IF_4}^+$ 

ii) $\underline{SF_5}^+$ 

iii) $\underline{NF_4}^-$ 

iv) $\underline{BF_4}^+$ 

i) sp³ / ____________

ii) sp³ / ____________

iii) sp³ / ____________

iv) sp³ / ____________
8) State how many of each of the following types of elements of symmetry exist in chlorofluoromethane. (8 pts)

chlorofluoromethane
SP$^3$ hybridized

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
three fold axis of rotation, C
four fold axis of rotation, C
planes of symmetry
Use the MO correlation diagram below (where needed) to answer questions 10, 11, and 12.

\[
\begin{align*}
&\sigma_{2px}^* \quad \pi_{2py}^* \quad \pi_{2pz}^* \\
&\sigma_{2px} \quad \pi_{2py} \quad \pi_{2pz} \\
&\sigma_{2s}^* \quad \sigma_{2s} \quad \sigma_{1s}^* \\
&\sigma_{1s}
\end{align*}
\]

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)

<table>
<thead>
<tr>
<th></th>
<th>CO</th>
<th>BN</th>
<th>BeC</th>
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<tr>
<td>Bond length</td>
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<tr>
<td>Bond enthalpy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of unpaired electrons</td>
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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)

\[
\text{bond order} =
\]

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

\[
\_\_\_\_ < \_\_\_\_ < \_\_\_\_
\]

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 BNH₂Cl₂ 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)

\[
\begin{array}{c}
\text{trans} \\
\text{cis}
\end{array}
\]

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

i) 8.48x10⁻¹⁹  ii) 4.97x10⁻¹⁹  iii) 3.52x10⁻¹⁹  iv) 2.67x10⁻¹⁹

ANSWER IS: _______

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

<table>
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<tr>
<th>Period</th>
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<th>II</th>
<th>III</th>
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<th>VII</th>
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Beneath most symbols are electronegativity values. Please use them where necessary in answering this question.

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

16) List the following in order of decreasing radius. Na⁺, Mg⁺, and 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) 

\[ \text{______} < \text{______} < \text{______} \]

18) List the following ions in order of decreasing ionic radius. 

$Li^+$, $Be^{3+}$, and $B^+$ (6 pts) 

\[ \text{______} > \text{______} > \text{______} \]

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

\[ \text{______} > \text{______} > \text{______} \]

20) List the following atoms in order of decreasing 3rd ionization energy. $Li$, $Na$, and $Al$ (6 pts) 

\[ \text{______} > \text{______} > \text{______} \]

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) 

\[ \text{H-H} \quad \text{C-H} \quad \text{C-O} \quad \text{N-N} \]

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

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

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

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

\[ \varepsilon = h \nu \]

\[ N_A = 6.022 \times 10^{23} \]

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

\[ \lambda \nu = c \]

\[ 1 \text{ Å} = 0.1 \text{ nm} = 10^{-8} \text{ cm} = 10^{-10} \text{ m} \]

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

Heisenberg Uncertainty principle: \[ \Delta P \Delta X = \frac{h}{4\pi} \] \text{ where } p = mv

kinetic energy: \[ \varepsilon = \frac{1}{2} mv^2 = \frac{p^2}{2m} \] \text{ where } p = mv

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

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

\[ \varepsilon_n = -\frac{2.179 \times 10^{-18}}{n^2} \text{ J} \]

\[ \varepsilon = qV = h \nu - \Phi \]

UNIT RELATIONSHIPS

1 amp = 1 \( \frac{\text{coulomb}}{\text{sec}} \) \hspace{1cm} 1 volt-coulomb = 1 Joule

1 esu\(^2\) = 1 \(\text{erg cm} \) \hspace{1cm} 1 Watt = 1 \( \frac{\text{joule}}{\text{sec}} \)

1 Joule = 1\( \times 10^7 \) \(\text{erg} \) \hspace{1cm} 1 Joule = 1 \( \frac{\text{kg} \cdot \text{m}^2}{\text{sec}^2} \) \hspace{1cm} 1 erg = 1 \( \frac{\text{g} \cdot \text{cm}^2}{\text{sec}^2} \)
SCRAP WORK SHEET
SCRAP WORK SHEET