Write the first letter of your last name in this box. →

THE UNIVERSITY OF BRITISH COLUMBIA
Department of Chemistry
Chemistry 111 Final Examination

Sample Final 2012 Time Limit: 2.5 hrs

SURNAME:_____ GIVEN NAME(S):_____
(PRINTED CAPITALS IN INK) (PRINTED CAPITALS IN INK)

STUDENT NUMBER:_____ SIGNATURE:_____
(PRINTED IN INK) (SIGNED IN INK)

INSTRUCTIONS
1. Answer all questions on the examination paper.
2. Check that your examination contains pages numbered 1 through 18. The last sheet (pages 17 and 18), containing "Potentially Useful Information" and the Periodic Table, may be removed.
3. The only calculator permitted is the Sharp EL-510R. All other calculators will be confiscated by the examiners.
4. Unassembled models are allowed.
5. No electronic communication devices are permitted.

Check √ your lecture section:
___112 (MT(12:30)WF 12:00) Dr. Herring

REGULATIONS FOR EXAMINATIONS

1. Each candidate must be prepared to produce, upon request, a Library/AMS card for identification.
2. No candidates shall be permitted to ask questions of the invigilators, except in the cases of supposed errors or ambiguities in examination questions.
3. No candidates shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half-hour of the examination.
4. Candidates suspected of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be subject to disciplinary action
   (a) Having at the place of writing any books, papers or memoranda, calculators, audio or visual cassette players or other memory aid devices, other than those authorized by the examiners.
   (b) Speaking or communicating with other candidates.
   (c) Purposely exposing written papers to the view of other candidates. The pleas of accident or forgetfulness shall not be received.
5. Candidates must not destroy or mutilate any examination material; must hand in all examination papers; and must not take any examination material from the examination room without permission of the invigilator.

Marks			
Part	Maximum	Obtained	Initials
I	30		
II	12		
III	20		
IV	12		
V	18		
VI	14		
VII	15		
VIII	9		
Total	**130**		

PART I. Multiple Choice (30 marks total)

For each numbered statement below, select the letter corresponding to the best answer. There is only one correct answer per question. Each correct answer is worth 1 mark for Questions 1-10 and 2 marks for Questions 11-20.

1. Which of the following is not possible?
   A) 2*p*
   B) 4*d*
   C) 5*p*
   D) 3*f*
   E) 2*s*

2. What is the molecular shape of NF_3?

   (a) tetrahedral
   (b) square-planar
   (c) seesaw
   (d) trigonal pyramidal
   (e) none of the above

3. Which probably has the highest boiling point at 1.00 atm pressure?
   a) $H_2NCH_2CH_2NH_2$
   b) $CH_3CH_2CH_2NH_2$
   c) $(CH_3)_2NH$
   d) $CH_3CH_2NHCH_3$
   e) $(CH_3)_3N$

4. Which of the following orbitals have their lobes aligned along the *y* axis?
   I) d_{xy}
   II) d_{x2-y2}
   III) p_y
   IV) d_{yz}
   A) II and III
   B) I and IV
   C) I and II
   D) II and IV
   E) I and III

5. Choose the INCORRECT statement about $[NH_2]^-$.

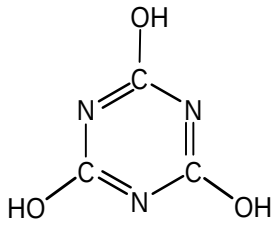
   (a) There are no π bonds.
   (b) There are two σ bonds.
   (c) N is sp^3 hybridized.
   (d) The ion is bent.
   (e) There is one lone pair on N.

6. Which two orbitals are located between the axes of a coordinate system and not along the axes?

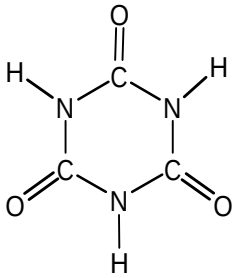
A) d_{xy}, p_y
B) d_{yz}, p_x
C) $d_{x^2-y^2}$, p_z
D) d_{xy}, d_{z^2}
E) d_{xy}, d_{yz}

7. Which is the correct molecular configuration for O_2^-?
A) $(\sigma_{1s})^2(\sigma_{1s}^*)^2\ (\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p})^2(\sigma_{2p})^2(\pi_{2p}^*)^2(\pi_{2p}^*)^1$
B) $(\sigma_{1s})^2(\sigma_{1s}^*)^2\ (\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p})^2(\sigma_{2p})^2(\pi_{2p}^*)^2$
C) $(\sigma_{1s})^2(\sigma_{1s}^*)^2\ (\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p})^2(\pi_{2p})^2\ (\sigma_{2p})^1(\pi_{2p}^*)^2$
D) $(\sigma_{1s})^2(\sigma_{1s}^*)^2\ (\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p})^2(\pi_{2p})^2\ (\sigma_{2p})^2(\pi_{2p}^*)^1$
E) None of these are correct.

8. Cyanuric acid exists in two forms (**A** and **B**) (lone pairs are not shown).



A



B

What is the maximum number of atoms that can lie in the same plane for form **A**?

(a) 6
(b) 8
(c) 9
(d) 10
(e) 12

9. What is the hybridization of each C and each N in form **B** of cyanuric acid (see question 8)?

(a) C = sp^3, N = sp^3
(b) C = sp, N = sp^3
(c) C = sp^3, N = sp^2
(d) C = sp^2, N = sp^2
(e) none of the above

10. According to M.O. Theory, which is the incorrect statement for C_2^-?
A) The bond order is 21/2.
B) There is one unpaired electron.
C) The σ_{2p} has one unpaired electron.
D) The molecule is paramagnetic
E) There are 9 electrons in the molecular orbitals.

11. An sp^3d hybridized central atom can be used to account for the bonding in molecules with all of the following molecular shapes:

(a) trigonal planar, trigonal bipyramidal, linear
(b) T-shaped, linear, trigonal bipyramidal
(c) linear, square planar, T-shaped
(d) see-saw, T-shaped, bent
(e) none of the above

12. Which of the following sets contains no substances with ionic bonds?

(a) $NaClO_4$, C_4H_{10}, NH_3
(b) NaCl, CH_4, S_8
(c) CO_2, HCN, O_2
(d) CO_2, NH_4Cl, C_2H_6
(e) AgCl, ScF_3, P_4

13. Which of the following statements is INCORRECT?

(a) The radius of Cl^- is greater than the radius of F^-.
(b) The radius of S^{2-} is greater than the radius of S.
(c) The radius of Rb is greater than the radius of K.
(d) The radius of Ca^+ is greater than the radius of Br^{2+}.
(e) The radius of F is greater than the radius of B.

14.) Which series of subshells is arranged in order of increasing energy in a multiple-electron atom?
A) 5*d*, 4*f*, 6*s*, 6*p*
B) 4*f*, 6*s*, 5*d*, 6*p*
C) 4*f*, 5*d*, 6*s*, 6*p*
D) 6*s*, 4*f*, 5*d*, 6*p*
E) 6*s*, 6*p*, 5*d*, 4*s*

15. Choose the INCORRECT statement.

(a) Electromagnetic radiation consists of propagating electric and magnetic fields.
(b) The velocity of ultraviolet light is greater than the velocity of X-rays.
(c) The energy of electromagnetic radiation is directly proportional to its frequency.
(d) Infrared light has a longer wavelength than ultraviolet light.
(e) A photon with a wavelength of 5000 Å has one-half as much energy as a photon with a wavelength of 2500 Å.

16. The boiling points of the halogens increase from F_2 to I_2. What type of intermolecular force is responsible for this trend?
a) dipole-dipole
b) hydrogen bonding
c) ion-ion attraction
d) London dispersion forces
e) ion-dipole interactions

17. The quantum numbers of the last electron of arsenic could be:
A) $n = 4, \ell = 2, m_\ell = 1, m_s = 1/2$
B) $n = 4, \ell = 1, m_\ell = 1, m_s = 1/2$
C) $n = 3, \ell = 1, m_\ell = 1, m_s = 1/2$
D) $n = 4, \ell = 3, m_\ell = 1, m_s = 1/2$
E) $n = 4, \ell = 1, m_\ell = 1/2, m_s = 0$

18. Which comparison of atomic and/or ionic radii is correct?
A) $K^+ > K$
B) $K^+ > Ca^{2+}$
C) Si > S
D) Kr > *X*e
E) $Cl > Cl^-$

19. The effective nuclear charge for sodium is:
A) <11, >10
B) <10, >9
C) <3, >1
D) <1, >0
E) 0

20. Which of the following reactions gives a positive value for the electron affinity?
A) $S^-(g) + e^- \rightarrow S^{2-}(g)$
B) $O(g) + e^- \rightarrow O^-(g)$
C) $S(g) + e^- \rightarrow S^-(g)$
D) $Br(g) + e^- \rightarrow Br^-(g)$
E) $C(g) + e^- \rightarrow C^-(g)$

PART II. (12 marks total)

1. Complete and balance these half-equations.

(a) $Cr_2O_7^{2-} \rightarrow Cr^{2+}$ (acidic solution)

(b) $MnO_4^- \rightarrow MnO_2$ (basic solution)

2. Balance the following equations in acidic or basic solution as indicated.

(a) $MnO_2 + ClO_3^- \rightarrow MnO_4^- + Cl^-$ (basic solution)

(b) $UO^{2+} + NO_3^- \rightarrow UO_2^{2-} + NO(g)$ (acidic solution)

(c) $I^- + IO_3^- \rightarrow I_3^-$ (acidic solution)

3. Balance the following reaction which does not occur in aqueous solution.

$ClO_2(g) + NH_3(g) \rightarrow N_2(g) + NH_4Cl(s) + H_2O(l)$

PART III. (20 marks total)

1. Draw one perspective diagram showing the VSEPR predicted shape for each of the following species. The central atom is underlined. In each case, specify the name for the shape (i.e. the molecular geometry) you have drawn.

(a) $\underline{C}H_2Cl_2$

Shape:

(b) $[\underline{Si}F_6]^{2-}$

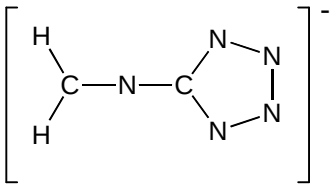
Shape:

(c) $[\underline{Xe}OF_3]^{+}$

Shape:

2. Draw ALL possible resonance structures for IO_3F (I is central atom) that contain only single and/or double bonds. Write any non-zero formal charges on the appropriate atoms, show all lone pairs of electrons as pairs of dots, and all bond pairs as lines. *Circle the best Lewis structure.*

3. Draw <u>ALL</u> possible resonance structures for the $[H_2C_2N_5]^-$ anion – all structures must have formal charges minimized. Write any non-zero formal charges on the appropriate atoms, show all lone pairs of electrons as pairs of dots, and all bond pairs as lines. The skeletal structure is:



4. A molecule with one lone pair of electrons has a pentagonal bipyramidal electron group geometry (EGG). Does the lone pair of electrons occupy an equatorial or an axial position? Briefly justify your answer.

PART IV. (12 marks total)

1 Arrange these compounds in order of increasing boiling point at 1 atm pressure. Briefly explain your reasoning.

(a) H_2O (b) H_2Se (c) H_2S

2 For each pair of compounds, pick the one with the highest boiling point. Briefly explain your reasoning.

(a) CH_3OH and CH_3SH

(b) CH_3OCH_3 and CH_3CH_3

(c) CH_4 and CH_3CH_3

3 Determine whether SCl_2 and SCl_4 are polar or not.

PART V. (18 marks total)

1. Specify the number of radial and angular nodes for each of the following orbitals.

$n = 2,\ \mathbf{l} = 0,\ m_l = 0$	angular_____	radial_____
$n = 4,\ \mathbf{l} = 2,\ m_l = 0$	angular_____	radial_____
$n = 5,\ \mathbf{l} = 2,\ m_l = -2$	angular_____	radial_____
$n = 10,\ \mathbf{l} = 7,\ m_l = -7$	angular_____	radial_____

2. Which of the following sets of quantum numbers are allowed and which are forbidden for an atomic orbital. Circle the correct answer for each.

$n = 3,\ \mathbf{l} = -2,\ m_l = 2$	allowed	forbidden
$n = 1,\ \mathbf{l} = 0,\ m_l = 0$	allowed	forbidden
$n = 56,\ \mathbf{l} = 2,\ m_l = -2$	allowed	forbidden
$n = 3,\ \mathbf{l} = 2,\ m_l = -½$	allowed	forbidden

3. Complete the following table by providing the appropriate elemental symbol and the ground state electronic configuration.

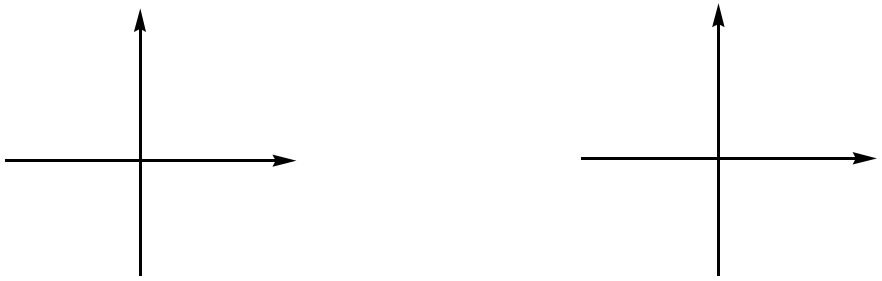
Species	Element	Electronic Configuration
The element with $Z = 7$.		
The fourth period atom with the most unpaired electrons.		

4. Complete the following table by providing the appropriate elemental symbol and the orbital diagram.

Species	Element	Orbital Diagram
An excited state of sulfur that is diamagnetic.		
The 2+ cation of the element with $Z = 26$.		

5. (a) Draw cross-sections for the following orbitals of the hydrogen atom. Show phases as (+) and (–) and label the axes.

$2p_z$ $4d_{xy}$



(b) Sketch the radial probability curve for the $4d_{xy}$ orbital using the axis system below. Assume that $r > 0$ and carefully label the axes.

PART VI. (14 marks total)

1. (a) Calculate the frequency of a photon required to excite the B^{2+} ion to the n = 3 state.

Frequency =_____

(b) Calculate the electron affinity of the B^{4+} ion when the electron is added to the n=1 level.

Electron Affinity =_____

(c) What is the ionization energy of the B^{3+} ion in the ground state?

Ionization Energy =_____

PART VII. (15 marks total)

1. Write a hybridization and bonding scheme for each molecule. Sketch the molecule, including overlapping orbitals, label each bond with an appropriate notation (e.g. σ(sp—sp))

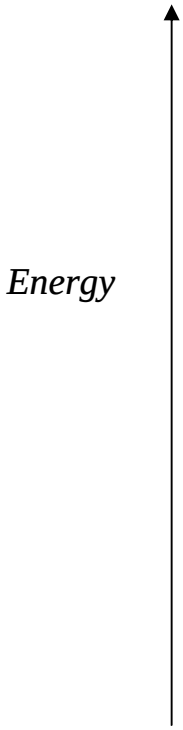
(a) NH_3

(b) NH_4^+

(c) CH_3NH_2 (skeletal structure H_3CNH_2)

PART VIII. (9 marks total)

1 On the scale below, draw an energy level diagram showing how the atomic orbitals interact to form the molecular orbitals of the diatomic anion in $\mathbf{N_2^-}$. Label the atomic and molecular orbitals with the appropriate symbols and place the appropriate number of electrons in each orbital. Determine the bond order for the diatomic anion $\mathbf{N_2^-}$.



Bond Order:

END OF EXAMINATION

Potentially Useful Information

1 Hertz = 1 Hz = 1 s^{-1} 1 J = 1 kg m^2 s^{-2}
1 m = 10^6 μm =10^9 nm = 10^{12} pm = 10^{10} Å

h = Planck's constant = 6.626×10^{-34} J s
N_A = Avogadro's number = 6.022×10^{23} mol^{-1}
c = speed of light = 3.00×10^8 m s^{-1}
1 amu = 1 u = atomic mass unit = 1.66×10^{-27} kg
electron mass = 9.11×10^{-31} kg
neutron mass = 1.67×10^{-27} kg

$E_n = -2.18 \times 10^{-18} \frac{Z^2}{n^2}$ J/atom