Chemistry 121

The University of British Columbia

Midterm Examination II

November 16, 2011

Time: 60 minutes

Put the first letter of your family/last name in this box.

Family/Last Name (printed):_____

First Name: _____

Signature:_____

Student Number:_____

Please check √ your lecture section:
___101 (MWF 1:00) MacLachlan
___102 (MWF 2:00) Wolf
___103 (MWF 3:00) New
___110 (MWF 10:00) New
___111 (MWF 11:00) MacLachlan
___122 (T,Th 2:00) Kunz
___133 (T,Th 3:30) MacFarlane
___188 (T,Th 8:00) Kunz
___199 (T,Th 9:30) Mehrkhodavandi

INSTRUCTIONS

1. Write all answers on this examination paper, and show full details of your solutions for Part 2.
2. Read each question carefully.
3. Check that this examination consists of **10 PAGES PRINTED ON BOTH SIDES**.
4. The only calculator allowed is the Sharp EL-510R. All other calculators will be confiscated. Cell phones or other electronic communication devices are not permitted.
5. Unassembled molecular model kits may be used.

RULES GOVERNING FORMAL EXAMINATIONS

1. Each candidate must be prepared to produce, upon request, a UBCcard for identification.
2. Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions.
3. No candidate shall be permitted to enter the examination room after the expiration of 15 minutes from the scheduled starting time, or to leave during the first 15 minutes 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 liable to disciplinary action:
   - having at the place of writing any books, papers or memoranda, calculators, computers, sound or image players/recorders/transmitters (including telephones), or other memory aid devices, other than those authorized by the examiners;
   - speaking or communicating with other candidates; and
   - purposely exposing written papers to the view of other candidates or imaging devices. The plea 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.
6. Candidates must follow any additional examination rules or directions communicated by the instructor or invigilator.

Marks

Part	Question	Possible Marks	Marks
1		**14**	
2	**1**	**6**	
	2	**8**	
	3	**2**	
	4	**6**	
	5	**6**	
	6	**4**	
	7	**6**	
	8	**8**	
Total		**60**	

Part 1. Multiple Choice (14 marks total)

For each numbered statement below, circle the letter that corresponds to the best answer. There is only one correct answer per question. Each question is worth 2 marks.

1. Which one of the following orbitals is lowest in energy in a Li^{2+} ion?

(a) 37*s*
(b) 12p_z
(c) 2$d_{x^2-y^2}$
(d) 5f_{xyz}
(e) 4d_{xz}

2. Arrange the following species in order of decreasing melting point:

CH_3OH ClBr S_8 Al Ar

(a) $S_8 > CH_3OH > ClBr > Ar > Al$
(b) $Al > ClBr > CH_3OH > S_8 > Ar$
(c) $S_8 > Al > ClBr > CH_3OH > Ar$
(d) $Al > S_8 > CH_3OH > ClBr > Ar$
(e) $CH_3OH > ClBr > S_8 > Ar > Al$

3. For a particular orbital of a hydrogen atom, there is a region of space where the wavefunction has a negative phase. Which one of the following statements is true?

(a) The oxidation state of the atom must be less than zero.
(b) Only destructive interference of the wavefunction can occur in that region.
(c) The wavefunction must correspond to a lobe of a *p*-orbital.
(d) There is a chance of finding the electron in that region of the orbital.
(e) The atom must be growing a moustache for Movember.

4. Which one of the following sets of quantum numbers {n, ℓ, m_ℓ,} would specify a wavefunction $\psi_{n,\,\ell,\,m_\ell}(r,\theta,\phi)$ that is a solution to the Schrödinger equation?

(a) {5, 2, −7}
(b) {8, 1, −1}
(c) {6, 6, −2}
(d) {0, 0, 0}
(e) {4, −2, 1}

5. Which of the following is <u>not</u> used or produced in the process to obtain white phosphorus?

(a) NaOH
(b) CO
(c) SiO_2
(d) C
(e) $Ca_3(PO_4)_2$

6. The melting point (mp) of xenon is −112 ˚C and the boiling point (bp) of xenon is −108 ˚C. The melting and boiling points of radon (Rn) are:

(a) mp = −137 ˚C; bp = −118 ˚C
(b) mp = −122 ˚C; bp = −110 ˚C
(c) mp = −35 ˚C; bp = 42 ˚C
(d) mp = −71 ˚C; bp = −62 ˚C
(e) mp = −53 ˚C; bp = −57 ˚C

7. A chemist shines a light on a metal surface, but no electrons are ejected. In order to make electrons eject from the surface of the metal, the chemist should:

(a) Increase the intensity of the light.
(b) Decrease the intensity of the light.
(c) Increase the frequency of the light.
(d) Decrease the frequency of the light.
(e) Choose a metal with a higher binding energy.

Part 2. Short Answer Questions

6 marks 1. For this question, consider only the following elements as possible answers:

Al, Si, P, S, Cl, Ar

For each part, give the symbol from the above list that makes the statement correct. Answers may be used more than once.

(a) _____ is involved in the thermite reaction.

(b) _____ exists as an allotrope with only one lone pair per atom.

(c) _____ is isoelectronic with Si in Mg_2Si.

(d) _____ exists as an allotrope that ignites spontaneously in dry air.

(e) _____ has the highest electronegativity.

(f) _____ commonly has an oxidation state of +2, +4, or +6 in compounds.

8 marks 2. Complete and balance the following reactions (assume sufficient heat is present to give a reaction – "no reaction" is not an acceptable answer):

(a) ___ Al + ___ O_2 $\rightarrow$

(b) ___ Mg + ___ CO_2 $\rightarrow$

(c) ___ H_2S + ___ SO_2 $\rightarrow$ (300 ˚C)

(d) ___ $\square$ + ___ $\square$ $\rightarrow$ ___ H_3PO_3

6 marks

2 marks

3. Silicon, germanium, and the grey allotrope of tin all have the same crystalline structure as diamond. The boiling points of these substances are:

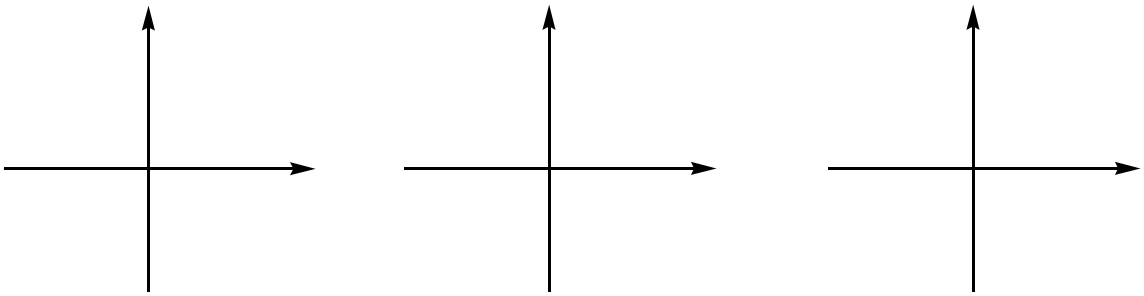
C (diamond)	bp ~4300 K
Si	bp = 3538 K
Ge	bp = 3106 K
Sn (grey form)	bp = 2875 K

Briefly rationalize the trend of decreasing boiling points in order of C > Si > Ge > Sn.

6 marks

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

$4d_{x^2-y^2}$ $2p_z$ $3s$

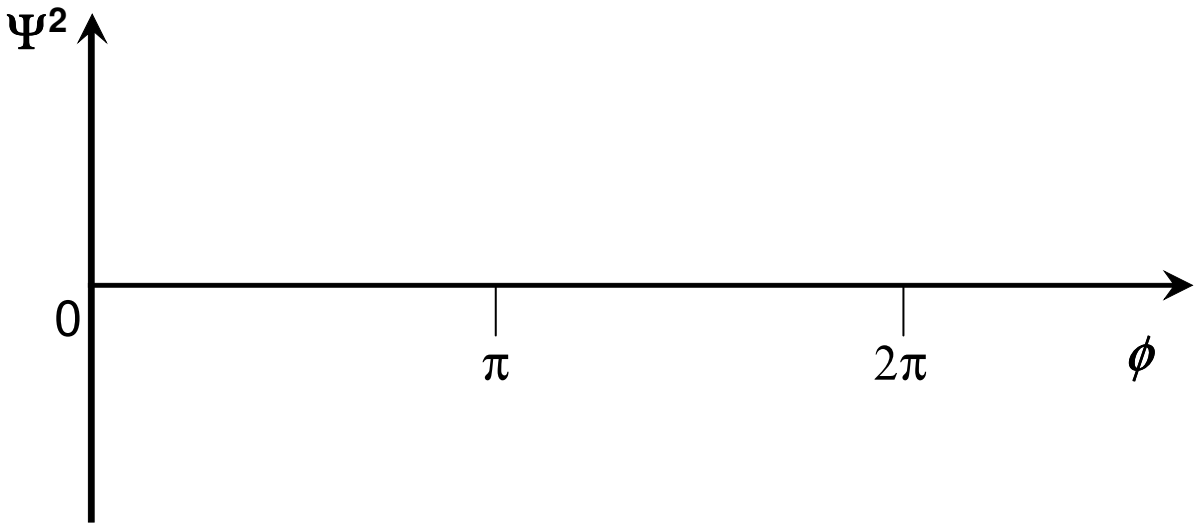


6 marks 5. Answer the following questions about the $6d_{z^2}$ orbital:

(a) The number of radial nodes in a $6d_{z^2}$ orbital is _____ .

(b) The number of angular nodes in a $6d_{z^2}$ orbital is _____.

(c) If $\Psi(r, \theta, \phi) < 0$ when $(r, \theta, \phi) = (q, 0, \pi/2)$, then plot Ψ^2 vs. ϕ for the $6d_{z^2}$ orbital when $r = q$ $(q > 0)$ and $\theta = \pi/2$ from $\phi = 0$ to 2π using the axes below.



4 marks

6. For parts (a) and (b), consider an electron moving with velocity = 3.5×10^5 m s^{-1}. Show all work for full credit.

(a) Calculate the de Broglie wavelength (in nm) of the electron.

(b) Calculate the wavelength (in nm) of light with energy that matches the kinetic energy of the electron.

6 marks

7. A sample of hydrogen-like ions initially in the ground state was selectively excited with a light pulse to generate ions in an excited state with n = 10. (Assume only one photon was absorbed by each ion to generate the excited state.) As the ions relaxed, photons were emitted from the sample. The lowest energy photons were selectively reflected onto a metal foil. When the metal was a sodium foil, electrons were ejected. No electrons were ejected when a calcium foil was used. (The binding energy of Na is 228.00 kJ mol^{-1} ; the binding energy of Ca is 277.00 kJ mol^{-1}). Show all work for full credit.

(a) Which transition(s) correspond to the lowest energy photons emitted from the sample? Specify the orbitals involved (e.g., 4p→1s).

(b) Identify the ion (and its charge) present in the sample: _____

(c) If the scientist inserts potassium foil into the beam path, predict whether she will detect electrons ejected from the potassium foil. Justify your answer.

8 marks 8. Under appropriate conditions (high temperature and pressure), the reaction of xenon (1 mol) with fluorine gas (3 mol) gives a new product **W** that is a colourless solid (**W** is the only product formed). Treating **W** (0.4 mol) with water (0.8 mol) gives a new product **Y** (0.4 mol) plus a weak acid **A** (1.6 mol). Compound **Y** reacts with additional water to give a new molecular compound **Z** and a by-product **Q** that does not contain oxygen. Analysis of the highly explosive solid **Z** shows that it contains only xenon and oxygen, and it has a polar structure.
(All of **A**, **Q**, **W**, **Y** and **Z** have a molecular weight < 320 g mol^{-1}.)

(a) Identify compounds **A**, **W**, **Y**, and **Z** with a chemical formula.

A:	**W:**	**Y:**	**Z:**

(b) Draw the best Lewis structure for compounds **Y** and **Z**. Draw only one resonance structure if resonance is possible. Clearly indicate any formal charges and show all lone pairs of electrons as pairs of dots and all bond pairs as lines.

Y:	**Z:**

End of Examination