Chemistry 121

The University of British Columbia

Midterm Examination I

October 12, 2011

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

Time: 60 minutes

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 **12 PAGES PRINTED ON BOTH SIDES.** The last sheet (pages 11 and 12), containing Supplementary Information and the Periodic Table may be detached for ease of use.
4. The only calculator allowed is the Sharp EL-510RB. 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	**6**	
	3	**12**	
	4	**5**	
	5	**6**	
	6	**6**	
	7	**5**	
Total		**60**	

Part 1. Multiple Choice (14 marks total)
For each numbered statement below, write the letter that corresponds to the best answer. There is only one correct answer per question. Each question is worth 2 marks.

1. When sodium burns in air with excess oxygen, it gives a product that

(a) dissolves in water to give an acidic solution
(b) has a covalent Na-O bond
(c) is stabilized by a triple bond
(d) has oxygen in the −1 oxidation state
(e) contains sodium in the +2 oxidation state

Answer:

2. Which one of the following series has four atoms or ions that are isoelectronic?

(a) C, Si, Ge, Sn
(b) C^{4+}, Si^{4+}, Ge^{4+}, Sn^{4+}
(c) B, C, N, O
(d) B^{2+}, C^{+}, N, O^{-}
(e) None of the above

Answer:

3. Which one of the following statements is false?

(a) the first ionization energy of bromine is larger than that of calcium
(b) the first ionization energy of barium is smaller than that of magnesium
(c) in a given row in the periodic table, the alkali metal always has the largest first ionization energy
(d) the melting points of the alkali metals decrease as their atomic weights increase
(e) the second ionization energy of an element is always greater than the first ionization energy

Answer:

4. In which one of the following species does N have a +1 formal charge in the best Lewis structure? (The underlined atom is the central atom.)

(a) H<u>C</u>N
(b) O<u>N</u>Cl
(c) [N<u>B</u>Cl]$^{-}$
(d) <u>N</u>I_3
(e) <u>N</u>$_2$O

Answer:

5. Bromine, with an atomic weight of 79.90 g mol^{-1}, has only 2 stable isotopes. One isotope of bromine, present in 50.7% natural abundance, has 44 neutrons in its nucleus. The other stable isotope of bromine is:

(a) ^{78}Br
(b) ^{79}Br
(c) ^{80}Br
(d) ^{81}Br
(e) ^{82}Br

Answer:

6. Which of the following compounds has an unpaired electron?

(a) SF_5
(b) SiF_4
(c) IF_5
(d) HNO_3
(e) $NaClO_4$

Answer:

7. Which one of the following molecules could exist in both polar and non-polar forms, depending on the arrangement of the halogen atoms? (the underlined atom is the central atom)

(a) $\underline{Xe}FCl$
(b) $\underline{Xe}Cl_2F_2$
(c) $\underline{Si}Cl_2F_2$
(d) $\underline{S}Cl_2F_2$
(e) $\underline{P}Cl_2F$

Answer:

Part 2. Short Answer Questions

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

Li, Na, K, Rb, Cs
Be, Mg, Ca, Sr, Ba

For each part, give the symbol from the above list that makes the statement correct.

(a) _____ has smallest atomic radius.

(b) _____ has valence electrons in the n = 4 shell with $Z_{eff} \sim 2$.

(c) _____ is the alkali metal that reacts most explosively with water.

6 marks 2. (a) Write a balanced equation for the reaction of rubidium with water.

(b) Write a balanced equation for the reaction of cesium oxide with oxygen.

(c) When magnesium nitride (Mg_3N_2) reacts with water, two products are formed. One of the products is a neutral compound with a mass of 17 g mol^{-1}. Using this information, write a balanced equation for the reaction of Mg_3N_2 with water.

12 marks 3. (a) Draw the best Lewis structure for each of the following ions. Draw only one structure when resonance is possible. 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.

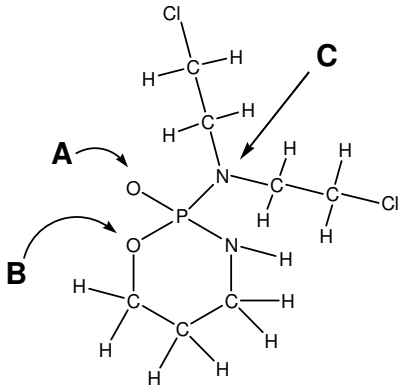
$[ClO_3]^-$ (the chlorate ion)	$[OF_3]^+$ (O is the central atom)	$[AsO_2Cl_2]^-$ (As is the central atom)

(b) Complete the following table by drawing the perspective diagram and specifying the molecular shape for each molecule. The central atom is underlined. In the last column, write "YES" if the molecule is polar, or "NO" if it is not polar.

Formula	Perspective Diagram	Molecular Shape	Is the molecule polar? (YES/NO)
$\underline{Sb}O_2Cl$			
$\underline{I}Cl_5$			
$\underline{Sn}Br_4$			

5 marks

4. Cyclophosphamide is a highly reactive molecule that binds to the guanine base of DNA, stopping cells from replicating. Cyclophosphamide is used to treat cancer. The following diagram shows the skeletal structure of cyclophosphamide. Answer parts (a) – (e) concerning the molecule below by circling the best answer.



a) The molecular shape at the atom labeled **B** is

(i) Tetrahedral
(ii) Linear
(iii) Trigonal Planar
(iv) Bent
(v) Trigonal Pyramidal

b) The estimated O-P-O bond angle is

(i) 90°
(ii) 120°
(iii) 109°
(iv) 145°
(v) 60°

c) The estimated C-N-C bond angle at the atom labeled **C** is

(i) 90°
(ii) 109°
(iii) 120°
(iv) 145°
(v) 60°

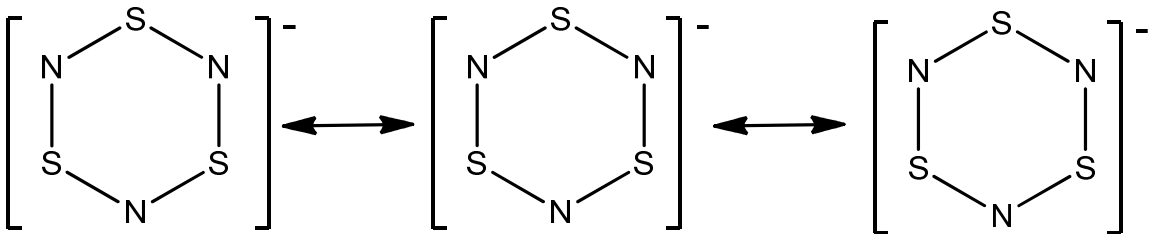
d) The number of atoms with tetrahedral molecular shape in cyclophosphamide is

(i) 7
(ii) 8
(iii) 9
(iv) 10
(v) 11

e) The formal charge on the atom labeled **A** in the best Lewis structure is

(i) −2
(ii) −1
(iii) 0
(iv) +1
(v) +2

6 marks 5. The anion $[S_3N_3]^-$ is a ring with alternating sulfur and nitrogen atoms. Complete the templates below by adding lone pairs and bonds to show the three <u>BEST</u> resonance structures for $[S_3N_3]^-$. Show all lone pairs of electrons as pairs of dots and all additional bonds as lines. Write any non-zero formal charges on the appropriate atoms.



Space for rough work:

6 marks 6. Ytterbium (Yb) metal crystallizes in a face-centered cubic (fcc) structure with unit cell edge length of 5.48 Å and density of 6.90 g cm^{-3} at 25 °C and 1 atm pressure (room temperature and pressure).

(a) What is the metallic radius of ytterbium (in Å)?

Answer: **Å**

(b) When ytterbium is compressed to 40,000 atm at 25 °C, it undergoes a phase change from a close-packed fcc to a body-centered cubic (bcc) lattice. In this high pressure form of Yb, what is the coordination number of Yb?

Answer:

(c) If the density of the high pressure (bcc) form of ytterbium is 8.71 g cm^{-3}, calculate the unit cell edge length of this structure.

Answer: **Å**

(d) The result described in part (b) was published in the science magazine, *Science*. *Science* only publishes surprising and breakthrough ideas. Briefly state why this paper was published in *Science*. (What is truly surprising about this result?)

5 marks 7. A chemist added 10.0 g of an unknown alkaline earth metal to 100 mL of 6 M sulfuric acid. After a vigorous reaction with evolution of a gas, only a clear, colourless solution remained. Next, she removed water and excess sulfuric acid from the solution by vacuum to leave a white solid. After recrystallization, she obtained 13.7 g of product, which represented a 65% yield. Chemical analysis of the white solid showed that it did not contain hydrogen. The white solid was found to be soluble in water and did not react with oxygen.

(a) Identify the unknown metal with a chemical symbol. You must show your work for credit.

(b) Write a balanced equation for the vigorous chemical reaction observed.

End of Examination

Supplementary Sheet

Potentially Useful Information

1 Hertz = 1 Hz = 1 s^{-1} = 10^{-6} MHz 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
proton mass = 1.67×10^{-27} kg
a_o = Bohr radius = 0.53 Å
R_H = Rydberg constant = 2.18×10^{-18} J
1eV = 1.60×10^{-19} J

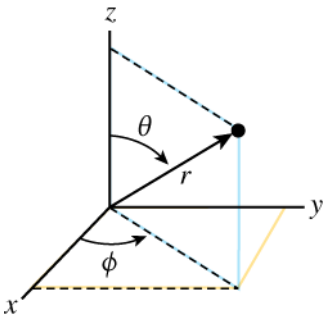
For one-electron species:

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

Particle in a one dimensional box:

$$E_n = \frac{h^2 n^2}{8mL^2} \quad (n = 1, 2, 3, \text{etc.})$$

Cartesian and Spherical Polar Coordinates:



PERIODIC TABLE OF THE ELEMENTS

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																1 H 1.008	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.99	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.064	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.9	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.7	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc "(98)"	44 Ru 101.07	45 Rh 102.9	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.33	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.98	84 Po "(209)"	85 At "(210)"	86 Rn "(222)"
87 Fr 223	88 Ra 226.03	89 Ac# 227.03	104 Rf	105 Db [261]	106 Sg	107 Bh	108 Hs	109 Mt									

*	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 145	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
#	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 260