Chemistry 121

The University of British Columbia

Midterm Examination II

November 14, 2012

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) Kunz
___102 (MWF 2:00) Wolf
___103 (MWF 3:00) Wolf
___110 (MWF 10:00) Mehrkhodavandi
___111 (MWF 11:00) Lekhi
___122 (T,Th 2:00) Burnell
___133 (T,Th 3:30) Burnell
___188 (T,Th 8:00) Rodriguez-Nunez
___199 (T,Th 9:30) Krems

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-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**	**5**	
	2	**8**	
	3	**8**	
	4	**5**	
	5	**4**	
	6	**8**	
	7	**8**	
Total		**60**	

Part 1. Multiple Choice (14 marks total)

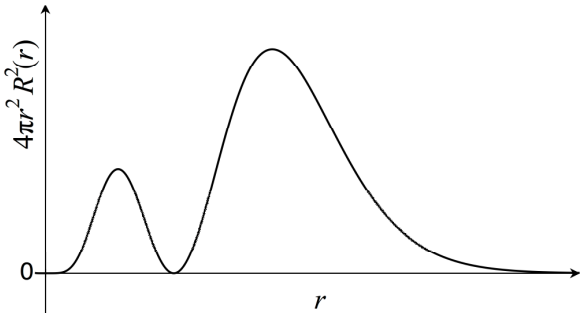
For each numbered statement below, circle the letter that corresponds to the best answer. There is only one correct answer per question. Each question is worth 2 marks.

1. Which of the following statements is FALSE?

(a) The product of wavelength and momentum of an electron is a constant.
(b) It is impossible to simultaneously measure precisely both position and momentum of a microscopic particle.
(c) Neutrons have no charge.
(d) Electrons may behave both as particles and as waves, but protons can only behave as particles.
(e) Electromagnetic radiation of all wavelengths travels at the same velocity in vacuum.

Answer:

2. The radial probability distribution for a particular orbital of the hydrogen atom with $n = 3$ is shown. Which of the following orbitals is represented by this distribution?



(a) $3s$
(b) $3p_x$
(c) $3d_{xy}$
(d) $3d_{x^2-y^2}$
(e) $3d_{yz}$

Answer:

3. Arrange the following species in order of increasing melting point:

Al_2O_3 Xe S_8 CH_3Cl C_{60}

(a) $Al_2O_3 < Xe < CH_3Cl < Br < C_{60} < S_8$
(b) $Xe < CH_3Cl < S_8 < C_{60} < Al_2O_3$
(c) $CH_3Cl < Xe < S_8 < Al_2O_3 < C_{60}$
(d) $Xe < CH_3Cl < C_{60} < S_8 < Al_2O_3$
(e) $CH_3Cl < Xe < Al_2O_3 < S_8 < C_{60}$

Answer:

4. Which of the following is a Lewis acid?

(a) H_2O
(b) BH_3
(c) H^-
(d) NH_3
(e) $[NH_4]^+$

Answer:

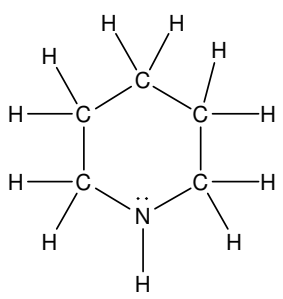
5. Hydrogen atoms are generated in an excited state where the electron occupies the 2*p* orbital. The excited sample of atoms then emits radiation that is directed to an unknown metal. The radiation ejects electrons with kinetic energy 8.77×10^{-19} J. Given the data in the table below, identify the unknown metal.

Metal	Ag	Cr	Ca	Mg	Au
Binding energy (J)	7.58×10^{-19}	7.21×10^{-19}	4.60×10^{-19}	5.86×10^{-19}	8.17×10^{-19}

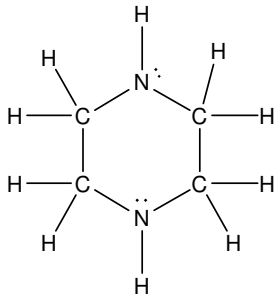
(a) Ag
(b) Cr
(c) Ca
(d) Mg
(e) Au

Answer:

6. The Lewis structures of two organic compounds (**A** and **B**) are shown below. Molecule A has a boiling point of 106 °C, and molecule **B** has a boiling point of 146 °C.



A



B

The major reason **B** has a higher boiling point than **A** is:

(a) Molecule **B** is nonpolar while molecule **A** is polar.
(b) Molecule **B** has a larger molecular weight than molecule **A**.
(c) Molecule **B** has more hydrogen bonding than molecule **A**.
(d) Molecule **B** has less hydrogen bonding than molecule **A**.
(e) Molecule **B** is polar while molecule **A** is nonpolar.

Answer:

7. What is the wavelength of radiation with 200.0 kJ/mol of energy?

(a) 167 nm
(b) 598 nm
(c) 5.98×10^{5} nm
(d) 1.67×10^{5} nm
(e) 9.93×10^{-22} nm

Answer:

Part 2. Short Answer Questions

5 marks 1. Fill in the blanks, using only elements from the third period of the periodic table and their compounds.

(a) _____ reacts with oxygen to give two gases _____ and _____. The molecules of one gas are polar, the molecules of the other gas are nonpolar.

(b) _____ reacts with oxygen to give a network covalent solid _____.

(c) _____ does not form any compounds that can be isolated at room temperature.

(d) _____ forms an amphoteric oxide with the empirical formula X_2O_3

8 marks 2. Balance the following equations by adding the appropriate stoichiometric coefficients, and draw a Lewis structure for the product formed in each case (assume sufficient heat is present to give a reaction in each case). 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.

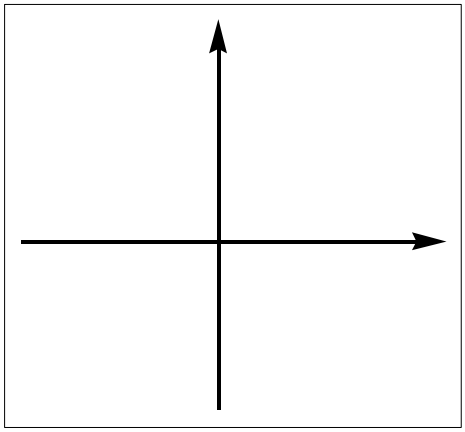
(a) $As_4O_6 + 6H_2O \rightarrow$ _____

(b) $P_4 + 10Br_2 \rightarrow$ _____

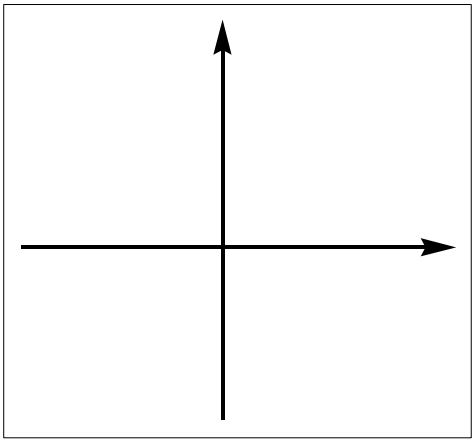
(c) $Si + 2I_2 \rightarrow$ _____

8 marks 3. (a) Draw cross-sections for the following orbitals of the hydrogen atom. Show phases as (+) and (–) and label the axes.

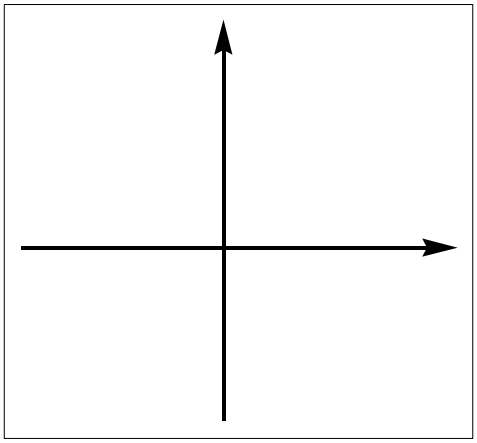
$4d_{xy}$



$2s$



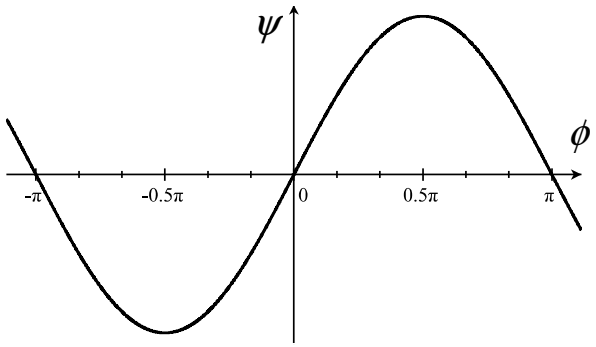
$3p_x$

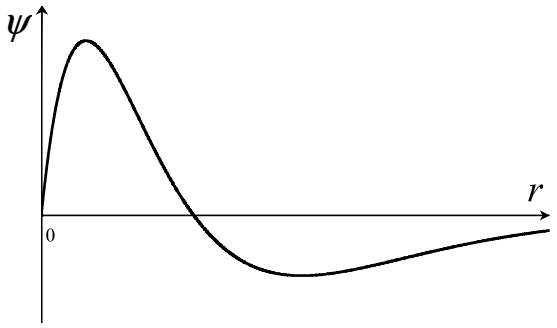


(b) The electron in the hydrogen atom can transition between orbitals while emitting or absorbing radiation. By drawing **single-headed** arrows (→), connect the boxes in part (a) to show the transitions that emit radiation.

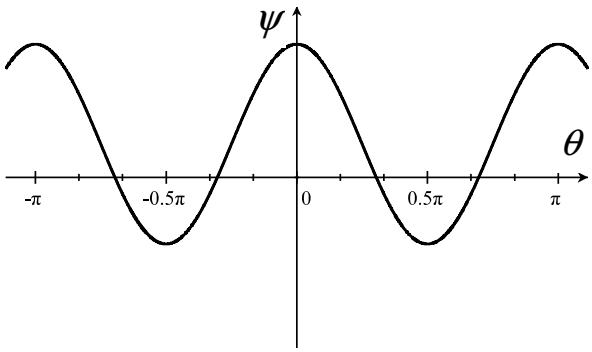
5 marks 4. The sketches below show the radial and angular parts of the wavefunction of two orbitals. Label each sketch with the appropriate orbital label (e.g. 1*s*, 2*s*, 2p_x, etc.). Angles θ and ϕ are the spherical polar coordinates.

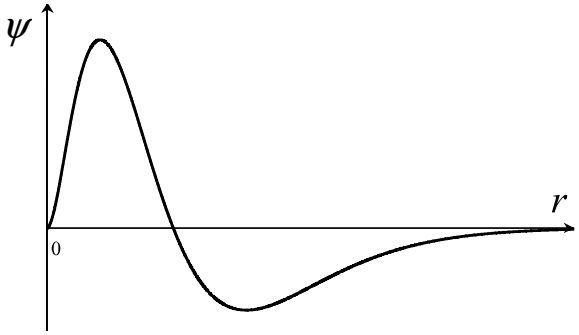
Orbital **A**: _____





Orbital **B**: _____





4 marks 5. The longest wavelength of light that causes ionization of the electron from the 4*p* orbital of an excited one-electron species is 58.4 nm. Identify the one-electron species in the box below, and use the additional space to show your work.

Species:

8 marks

6. Electrons in molecules with alternating single and double bonds can move freely within the molecule. Consider β-carotene, the compound which gives carrots their characteristic colour. β-carotene can be represented by a one-dimensional box of size 1.85 nm with 11 quantum states occupied by electrons. The lowest energy absorption of light by β-carotene involves the transition of an electron from the n = 11 state to the n = 12 state.

(a) How many nodes does the wavefunction of the n = 11 state have?

Answer:

(b) Use the particle in a one-dimensional box model for the electrons in β-carotene to calculate the kinetic energy (in Joules) of an electron in the n = 11 state.

Answer:

(c) Use the particle in a one-dimensional box model to calculate the wavelength of light in nm that can excite an electron from the $n = 11$ state to the $n = 12$ state in β-carotene.

Answer:

(d) Given that the visible region of the electromagnetic spectrum spans the range 390-760 nm, explain why the presence of β-carotene gives carrots an orange/red colour.

8 marks 7. The reaction of PCl_3 (1 mol), CH_3Cl (1 mol) and $AlCl_3$ (1 mol) results in the formation of one product, an ionic solid **X**. Both the cation and anion in **X** have a tetrahedral molecular shape at the central atoms. The anion contains only Al and Cl. Reaction of **X** (1 mol) with H_2O (1 mol) results in the formation of a compound **Y**, as well as HCl (1 mol) and $HAlCl_4$ (1 mol).

(a) Write chemical formulae for **X** and **Y**.

(b) Draw Lewis structures of both the cation and anion in **X**. 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.

Cation in X:

Anion in X:

(c) Draw a Lewis structure for **Y**.

Lewis structure of Y:

Show your work here

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

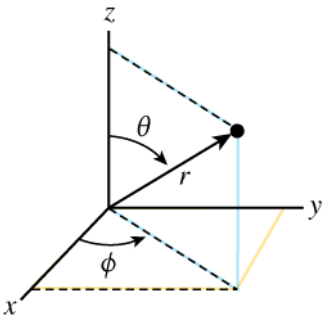
For one-electron species:

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

Particle in a one dimensional box:

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

Cartesian and Spherical Polar Coordinates:



PERIODIC TABLE OF THE ELEMENTS

Group 1																17	18
1 H 1.008	2											13	14	15	16	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	3	4	5	6	7	8	9	10	11	12	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