Name:______SOLUTIONS III, IV, and V________ Section (circle): 1 2 3 4 5

SAMPLE EXAM 2 FALL 2012 SOLUTIONS

Chemistry 11, Fall 2007

Exam II

November 15, 2007

7:30 PM – 9:30 PM

As always, full credit will not be given unless you have written down the reasoning or calculations you used to obtain the correct answer. **Work on the back of pages will not be graded!** Pay attention to significant figures. Please check now that your exam has thirteen pages (including this one). A periodic table and a list of formulas are attached at the back of the exam. If you finish early, just leave your completed exam on the front desk. If you have a question, we will be in an out during the exam. You have two hours to complete this exam.

It is against the honor code at Amherst College to either give or receive help on this exam. The work you turn in must be yours and yours alone.

Extra Credit (circle the correct answer)

What was Schrodinger's First name?

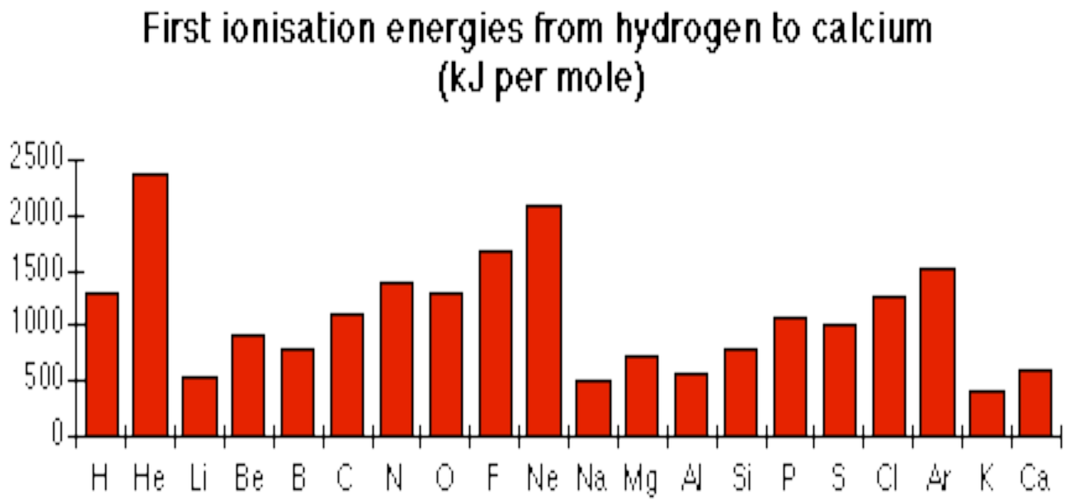
a) Kitty
b) Richmond
c) Erwin
d) Zeynep

Question	Points	Score
XC	02	
I	25	
II	25	
III	20	
IV	20	
V	10	
Total	102	

I. IE, Lewis Structures, VSEPR, dipoles (25 points)

1. Arrange the following elements in order of increasing size (atomic or ionic radii). Explain your arrangement. (5 pts)
Al, Ar, Cl, Mg, Na, P, S, Si, Cl^-, K^+.

2. The first ionization energies of the first 20 elements are shown in this graph. (5 pts)



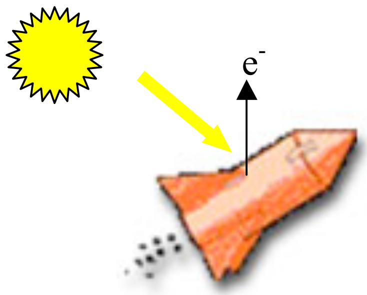
Explain the trend in ionization energy from sodium to argon. Make sure your answer includes the special cases in the trends (i.e. magnesium > aluminum, phosphorus > sulfur.; argon > potassium.)

3. For each of the following molecules/molecular ions, draw the Lewis diagram, indicating the formal charge on each atom, the geometry (shape) of the molecule, the bond angles, the direction of polarity in each bond and where applicable, the direction of the molecular dipole. Sulfur is always the central atom, and the electronegativity values of sulfur, fluorine and oxygen are 2.6, 4.0 & 3.4 respectively. (15 pts)
.

SO	SO_2
SO_3	$[SO_3]^{-2}$
$[SO_4]^{-2}$	SF_6

II. PE effect, Ionization Energy (25 points 5 pts each)

Light can knock electrons off of a metallic surface, causing the surface to be positively charged; this process is called the photoelectric effect. For a metallic spacecraft orbiting in sunlight, the photoelectric effect could result in the spacecraft's surface becoming positively charged. Surface charging of a spacecraft might then cause electrical discharges that could damage its surface or delicate electronic components.



Assuming the energy of sunlight to be 4.26 eV, suppose you were to build a spacecraft using one of the following metals; magnesium, aluminum or titanium. The work functions for these metals are 3.68eV, 4.28eV and 4.33eV, respectively. (1eV= 1.602177 x 10^{-19}J)

a) What is the meaning of work function? Which of these metals would you prefer to avoid surface charging of your spacecraft? Explain.

b) If all three metals were used in the building of the spacecraft, would any electrons be knocked off? If so with what kinetic energy?

c) Use the information in the table below to draw the relative energy level diagrams for the valence orbitals (i.e. 3s and 3p) for Na, Mg and Al metals.

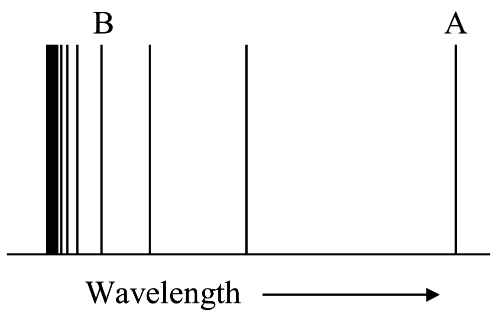
	1^{st} Ionization P. (eV)	2^{nd} Ionization P. (eV)	3^{rd} Ionization P. (eV)
Na	5.139	47.286	71.641
Mg	7.646	15.035	80. 143
Al	5.986	18.828	28.447

d) Why is the 2nd ionization potential of Na so much higher than the 2^{nd} ionization potential of Mg?

e) Which of the three metals would have higher 4^{th} ionization energy? Why?

III (Early Quantum Ideas) 20 points (4 points each)

1. The figure below shows a portion of the emission spectrum of a one-electron atom in the gas phase. All of the lines shown result from transitions from excited states to a final state of n = 4.



a. What transition corresponds to line A (i.e., what are the initial and final states of this transition)?
Line A represents the lowest energy (longest wavelength) transition of all possible transitions from excited states to a final state of n=4. Because Line A corresponds to the lowest energy transition, it must be due to the transition from n=5 to n=4.

b. The wavelength at which line B occurs is 216 nm. What is the energy of a single photon of light with this wavelength?

$$E = h\nu = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,J\cdot s)(3.00\times10^{8}\,m\cdot s^{-1})}{216\times10^{-9}\,m} = 9.20\times10^{-19}\,J$$

c. Line B in the figure corresponds to the transition from n = 8 to n = 4. Based on this information and the energy determined in part (b), what is the identity of this one-electron atom (or ion)? Show all of your work.
In order to identify the ion, the Z must be calculated. Also, because the transition involves emission of a photon ΔE in the Bohr equation is negative.

$$\Delta E = \left(-2.178\times10^{-18}\text{ J}\right)\left(Z^2\right)\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)$$

$$9.20\times10^{-19}\,J = \left(-2.178\times10^{-18}\text{ J}\right)\left(Z^2\right)\left(\frac{1}{4^2}-\frac{1}{5^2}\right)$$

Z=3, which is the atomic number of the element, or the number of protons the element possesses, so Z=3 indicates that the identity of the element is lithium. For the Bohr model to be applicable, the element can only have one electron. Therefore the identity of the ion, including the charge, is Li^{+2}.

d. The atom (ion) will not remain in the state n = 4, as this is an excited state. When the atom (ion) undergoes a transition from n = 4 to n = 1, what wavelength of light will be emitted?

$$\Delta E = \left(2.178\times10^{-18}\ \text{J}\right)\left(Z^2\right)\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right) = (2.178\times10^{-18})(9)\left(\frac{1}{1_f^2}-\frac{1}{4_i^2}\right) = (2.178\times10^{-18})(9)\left(\frac{15}{16}\right)$$

$$\Delta E = 1.654\times10^{-17}\,J$$

$$E = \frac{hc}{\lambda}\ rearranging\ldots\ldots\lambda = \frac{hc}{E} = 1.202\times10^{-8}\,m = 12.02\,nm$$

This light will be in the UV

2. Nothing can move at a speed greater than the speed of light. This fact suggests that the maximum uncertainty in the speed of any particle or object is the speed of light. Using this information and the uncertainty principle, show that an electron cannot be confined to the nucleus of an atom. Assume that the radius of the nucleus is approximately 1×10^{-15} m.

Using the maximum uncertainty in the velocity of an object, the minimum uncertainty in its position can be found. For an electron in an atom, if this minimum uncertainty is greater than the radius of the nucleus, it is valid to say that the electron cannot be confined to the nucleus. The minimum uncertainty in the position of the electron is found using Heisenberg's uncertainty principle, with $\Delta v = c$, the speed of light.

$$\Delta x \cdot \Delta p = \Delta x \cdot m\Delta v = \frac{h}{4\pi}$$

$$\Delta x = \frac{h}{4\pi \cdot m_e \cdot \Delta v} = \frac{6.626\times10^{-34}\,J\cdot s}{4\pi\cdot 9.10939\times10^{-31}\,kg\cdot 3.00\times10^{8}\,m\cdot s^{-1}} = 1.93\times10^{-13}\,m$$

Because the minimum uncertainty in the position of the electron exceeds the radius of the nucleus, the electron cannot be confined to the nucleus.

IV. Quantum Mechanics (20 points; questions 1 and 2 each 10 pts)

1. Orbitals; some have smooth curves while others are very curvy and full of radial nodes. Orbitals vary in size, shape, phases, and energies. **ANSWER ANY TEN OF THE FOLLOWING TWELVE**.

There are __**25**_ orbitals with n=5.

As n increases, the energy **increases**____.

Every orbital with n = ____**5**___ has 4 nodes.

Every orbital with ℓ= ___**1**__ has 1 nodal plane.

There are __**50**__ different electrons that can have n = 5.

If ℓ = 1; m_ℓ = 0 the orbital is oriented along the ___**z**___ axis.

Orbitals with ℓ = 0 can only have _**radial** nodes (answer is not a number)

Electrons can occupy the same orbital ONLY if they have opposite __**spin**___.

Electrons in the same orbital have the same **n, ℓ , m_ℓ**, m_s (circle whichever are correct).

For multi-electron atoms, the energy depends on **n, ℓ** , m_ℓ, m_s (circle whichever are correct)

Orbitals with ℓ > 0 always have _**planar**__nodes but may also have _**radial**__ nodes. (answers are not numbers).

2. We have shown how our quantum numbers determine the shape of the periodic table, with its s block, p block, and d block elements. If the quantum number rules were different, our periodic table would have a different shape, and groups (i.e. alkali or noble gases) would have different identities.

a) Draw below the periodic table if the quantum number rules were as follows (Pauli, Aufbau, Hund's rules still apply):
n = 1, 2, 3, 4 , ℓ= 0, 1, m_ℓ = 0, 1, m_s = ± ½
With the quantum rules above, we would NOT have the same restrictions on ℓ and m_ℓ
And the periodic table that would result would have an s block (filling in of ℓ =0) that is 4 elements wide, and a p block (filling in of ℓ =1) that is also 4 elements wide. Shown below is the periodic table with the s block shown in turquoise and the p block in yellow, with the quantum number shown of the last electron to be put in

100½	100 -½	101 +½	101 -½	110 +½	110 -½	111+½	111-½
200½	200 -½	201 +½	201 +½	210 +½	210 -½	211+½	**211-½**
300½	300 -½	301 +½	301 +½	310 +½	310 -½	311+½	311-½
400½	400 -½	401 +½	401 +½	410 +½	410 -½	411+½	411-½

b) Give the electron configurations for the element that is the 2nd noble gas and also the element that is the 2nd alkali element.

Electron configuration of the 2nd noble gas in this new periodic table: **noble gases have their outer shells full, so the second noble gas is the element at the end of the second row, and has the electron configuration: $1s^4 1p^4 2s^4 2p^4$ shown above with its last electron 211+½**

Electron configuration of the 2nd alkali element: **alkali elements have only one electron in their outer shell, so the second alkali element would be the first element in the second row, with an electron configuration of $1s^4 1p^4 2s^1$**

V Lab (10 points) Save the Yellow Fish

Alas, the water in Nemo's fish tank has suddenly turned cloudy, and we suspect foul play! We know that Jess-c's room mate doesn't really like the fish, and is bothered by the bubbling sound of the filter. She finds next to her room mate's desk, an opened box of baking soda ($NaHCO_3$), a box of chalk with one piece suspiciously missing ($CaCO_3$), a half filled bottle of balsamic vinegar (acetic acid - CH_3COOH), a bottle of windex with ammonia (NH_3), and a salt shaker (NaCl). Did her room mate add one of these chemicals to the tank in an act of ultimate evil? Jess remembers back to the Baker's Street Dozen Lab, and remembers that these compounds react in a predictable way with some other chemicals, and have characteristic odors and pHs when dissolved in water. She creates a grid which might help her to discover which (if any) of these poisons was added to the aquarium. Help Jess fill in the grid of what she might EXPECT to happen if she tests the chemicals in the prescribed manner or mixes the reagents in the top row with the suspected poisons in the first column.

	pH paper	**+ $AgNO_3$**	**+ HCl**	**+ NaOH**	**Odor**
$NaHCO_3$	basic	Slight ppt	Bubbles, warm	NR	none
$CaCO_3$	Very basic	ppt	Bubbles, heat	NR	none
CH_3COOH	acidic	NR	NR	Heat-neutralizes	vinegar
NH_3	basic	ppt	Heat, neutralize	NR	Ammonia- Window cleaner
NaCl	neutral	ppt	NR	NR	none

Jess brings a 100 mL sample of potentially "poisoned" water to the chem. lab, and Professors Dey and Amp-Bon help her to do the actual experiment. Here is what they discovered:

The aquarium water has a pH 10-12, makes a cloudy white precipitate with $AgNO_3$, bubbles when a hydrochloric acid is added, and the solution gets a bit hot. They see no reaction with NaOH and don't smell anything "fishy" from the aquarium water.

What "poison" can they deduce might have been added to the water? Explain your reasoning.
$CaCO_3$ is the best choice because it forms a ppt (AgOH and AgO_2) with AgCl, is quite basic (more basic than $NaHCO_3$, and forms CO_2 bubbles when HCl is added. It also has no odor.

Assorted Equations, Constants, and Conversion Factors

Wavelength, frequency, speed relation for waves: $\lambda\nu = c$

Photon energy: $E_{photon} = h\nu = \frac{hc}{\lambda}$

Photoelectric effect: $E_{photon} = E_o + E_{kinetic}$

Kinetic energy: $E_{kinetic} = \frac{1}{2}mv^2$

deBroglie wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$

Heisenberg's uncertainty principle: $\Delta p \times \Delta x \geq \frac{h}{4\pi}$ or $m\Delta v \times \Delta x \geq \frac{h}{4\pi}$

Energy levels of a one-electron atom: $E_n = \left(-2.178 \times 10^{-18}\ J\right)\left(\frac{Z^2}{n^2}\right)$

$$\Delta E = \left(-2.178 \times 10^{-18}\ J\right)\left(Z^2\right)\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Avogadro's number: $N_A = 6.022 \times 10^{23}$ mol^{-1}

Speed of light: $c = 2.9979 \times 10^8$ m s^{-1}

Planck's constant: $h = 6.626 \times 10^{-34}$ J s

Fundamental charge: $e = 1.60218 \times 10^{-19}$ C

Proton mass: $m_p = 1.673 \times 10^{-27}$ kg

Neutron mass: $m_n = 1.675 \times 10^{-27}$ kg

Electron mass: $m_e = 9.109 \times 10^{-31}$ kg

1 kg = 10^3 g

1 nm = 10^{-9} m

1 J = 1 N m = 1 kg m^2 s^{-2}

1 kJ = 10^3 J

WebElements: the periodic table on the world-wide web

http://www.webelements.com/

Key: element name / **atomic number** / symbol / atomic weight (mean relative mass)

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen **1** H 1.0079																		helium **2** He 4.0026
lithium **3** Li 6.941	beryllium **4** Be 9.0122												boron **5** B 10.811	carbon **6** C 12.011	nitrogen **7** N 14.007	oxygen **8** O 15.999	fluorine **9** F 18.998	neon **10** Ne 20.180
sodium **11** Na 22.990	magnesium **12** Mg 24.305												aluminium **13** Al 26.982	silicon **14** Si 28.086	phosphorus **15** P 30.974	sulfur **16** S 32.065	chlorine **17** Cl 35.453	argon **18** Ar 39.948
potassium **19** K 39.098	calcium **20** Ca 40.078		scandium **21** Sc 44.956	titanium **22** Ti 47.867	vanadium **23** V 50.942	chromium **24** Cr 51.996	manganese **25** Mn 54.938	iron **26** Fe 55.845	cobalt **27** Co 58.933	nickel **28** Ni 58.693	copper **29** Cu 63.546	zinc **30** Zn 65.39	gallium **31** Ga 69.723	germanium **32** Ge 72.61	arsenic **33** As 74.922	selenium **34** Se 78.96	bromine **35** Br 79.904	krypton **36** Kr 83.80
rubidium **37** Rb 85.468	strontium **38** Sr 87.62		yttrium **39** Y 88.906	zirconium **40** Zr 91.224	niobium **41** Nb 92.906	molybdenum **42** Mo 95.94	technetium **43** Tc [98]	ruthenium **44** Ru 101.07	rhodium **45** Rh 102.91	palladium **46** Pd 106.42	silver **47** Ag 107.87	cadmium **48** Cd 112.41	indium **49** In 114.82	tin **50** Sn 118.71	antimony **51** Sb 121.76	tellurium **52** Te 127.60	iodine **53** I 126.90	xenon **54** Xe 131.29
caesium **55** Cs 132.91	barium **56** Ba 137.33	**57-70** *	lutetium **71** Lu 174.97	hafnium **72** Hf 178.49	tantalum **73** Ta 180.95	tungsten **74** W 183.84	rhenium **75** Re 186.21	osmium **76** Os 190.23	iridium **77** Ir 192.22	platinum **78** Pt 195.08	gold **79** Au 196.97	mercury **80** Hg 200.59	thallium **81** Tl 204.38	lead **82** Pb 207.2	bismuth **83** Bi 208.98	polonium **84** Po [209]	astatine **85** At [210]	radon **86** Rn [222]
francium **87** Fr [223]	radium **88** Ra [226]	**89-102** **	lawrencium **103** Lr [262]	rutherfordium **104** Rf [261]	dubnium **105** Db [262]	seaborgium **106** Sg [266]	bohrium **107** Bh [264]	hassium **108** Hs [269]	meitnerium **109** Mt [268]	darmstadtium **110** Ds [281]	roentgenium **111** Rg [272]	ununbium **112** Uub [285]	ununtrium **113** Uut [284]	ununquadium **114** Uuq [289]	ununpentium **115** Uup [288]	ununhexium **116** Uuh [292]		

*lanthanoids	lanthanum **57** La 138.91	cerium **58** Ce 140.12	praseodymium **59** Pr 140.91	neodymium **60** Nd 144.24	promethium **61** Pm [145]	samarium **62** Sm 150.36	europium **63** Eu 151.96	gadolinium **64** Gd 157.25	terbium **65** Tb 158.93	dysprosium **66** Dy 162.50	holmium **67** Ho 164.93	erbium **68** Er 167.26	thulium **69** Tm 168.93	ytterbium **70** Yb 173.04
**actinoids	actinium **89** Ac [227]	thorium **90** Th 232.04	protactinium **91** Pa 231.04	uranium **92** U 238.03	neptunium **93** Np [237]	plutonium **94** Pu [244]	americium **95** Am [243]	curium **96** Cm [247]	berkelium **97** Bk [247]	californium **98** Cf [251]	einsteinium **99** Es [252]	fermium **100** Fm [257]	mendelevium **101** Md [258]	nobelium **102** No [259]

Symbols and names: the symbols and names of the elements, and their spellings are those recommended by the International Union of Pure and Applied Chemistry (IUPAC - http://www.iupac.org/). Names have yet to be proposed for the most recently discovered elements 111–112 and 114 so those used here are IUPAC's temporary systematic names. In the USA and some other countries, the spellings **aluminum** and **cesium** are normal while in the UK and elsewhere the common spelling is **sulphur.**
Group labels: the numeric system (1–18) used here is the current IUPAC convention.
Atomic weights (mean relative masses): Apart from the heaviest elements, these are the IUPAC 2001 values and given to 5 significant figures. Elements for which the atomic weight is given within square brackets have no stable nuclides and are represented by the element's longest lived isotope.
 For updates to this table see http://www.webelements.com/webelements/support/media/pdf/. **Version date: 11 July 2005.**