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Do yourself a solid.

3.091 Introduction to Solid State Chemistry

Fall Term 2018
Exam 1
10/1/2018 (11:05 am – 11:55 am)

Name: ____

Recitation Section: ______ Recitation Instructor: ____________________________

A complete exam consists of five (5) questions on a total of eleven (11) pages.
Write your answers on these pages (you can use the back).
State your assumptions and show calculations that support your conclusions.

RESOURCES PERMITTED:
PERIODIC TABLE OF THE ELEMENTS
TABLE OF CONSTANTS
ONE AID SHEET (ONE PAGE 8.5” × 11”, DOUBLE-SIDED O.K.)
A STAND-ALONE CALCULATOR – GRAPHING O.K.

NO BOOKS OR OTHER NOTES ALLOWED.

USE OF WIRELESS COMMUNICATIONS DEVICES STRICTLY FORBIDDEN.

Problem 1	17 pts	
Problem 2	24 pts	
Problem 3	19 pts	
Problem 4	17 pts	
Problem 5	23 pts	
TOTAL	100 pts	

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Problem 1 (17 POINTS)

a) A Lithium ion (Li^{2+}) laser is emitting light of wavelength 450 nm due to electrons relaxing to energy level n=4 from some unknown energy level. What is the unknown energy level? [4 points]

b) Against all lab safety protocol (do. not. do), you grab a different laser and observe the light through your spectrometer. You observe 10 spectral lines. This means that there are at least how many possible energy levels? [2 points]

c) You purchase two new lasers that each emit one wavelength only: one emits 200nm light, and the other emits 900nm light. However, you mix up the lasers and don't know which is which. You shine each of these lasers onto a slab of metal. One laser ionizes electrons from the metal but the other doesn't. Which laser **doesn't** ionize the metal? Give one sentence explaining why. [2 points]

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d) You begin to increase the frequency of the laser you named in part c). If you continue doing this, will you eventually observe electrons being emitted? Give **one** sentence explaining why or why not. [2 points]

e) You begin to increase the intensity of the laser you named in part c). If you continue doing this, will you eventually observe electrons being emitted? Give **one** sentence explaining why or why not. [2 points]

f) You find an article that says that electrons in your metal slab will start to be ionized at 500nm. If you switch to the laser from part c) that **DOES** ionize the metal (i.e. the one you didn't give in your answer to c)) and shine it on said metal, what will be the velocity of the emitted electrons? [5 points]

NAME ____

Problem 2 (24 POINTS)

NOTE: For each of the following questions, assume the atom or ion is in the ground state.

a) Write the ground state electron configuration for the following atoms and ions. [6 points]

- O^{2-}
- Si

b) For the following atoms and ions, draw a box-and-arrow diagram to represent the last completely or partially filled subshell, following Aufbau's rules for filling. You may use noble gas abbreviations for filled inner shells. [6 points]

- O^{2-}
- Si

c) Paramagnetic materials are attracted by a magnetic field, but do not retain a magnetization when the external field is removed. Paramagnetism is caused by **unpaired electrons** in a material's atoms. Based on this information, which atom and/or ion in part A are paramagnetic, if any? [2 points]

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d) Write the complete set of quantum numbers (the values for *n, l,* m_l, m_s) for each of the valence electrons in Si. [8 points]

e) How many of the electrons in Si have the same set of quantum numbers (n, l, m_l, m_s)? [2 points]

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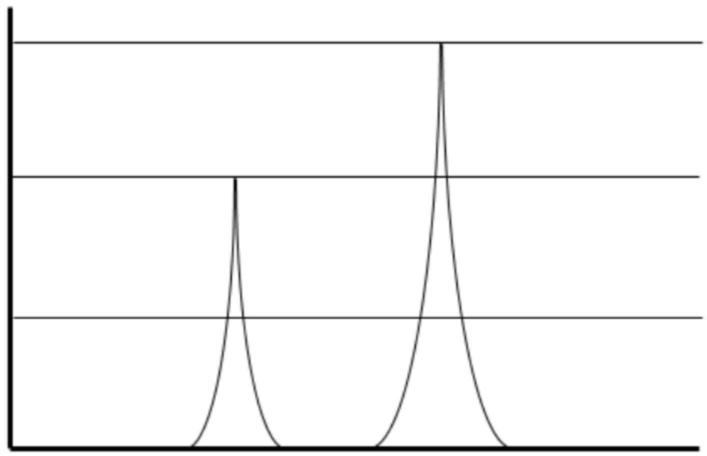
Problem 3 (19 POINTS)

Below is the PES spectrum for the outer electrons of element X.



a) Label the axes and the direction of increasing ionization energy on this graph. The graph is plotted so that the highest peak corresponds to the electrons that are ionized first during the experiment. [3 points].

b) Element X has the same inner electron configuration as neon. Identify element X and label the peaks by subshell, including the number of electrons in each peak.

Note: only the peaks corresponding to valence electrons are shown in the graph. [6 points].

c) Consider an ion with the same electronic configuration as X but one more proton. On the graph above, draw the new PES spectrum for this ion. [4 points].

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d) You were taking PES spectrum data for carbon in a vacuum. However, the seal on the vacuum machine broke and let in an unknown gas. The spectrum for carbon is still present, but you need to identify the unknown peaks. You observe the following on the contaminated spectrum:

i. There are 6 peaks total (including peaks from the carbon) on the spectrum
ii. Five peaks are of the same height
iii. One peak is three times higher than the others

What is the contaminating element? Explain your reasoning. [6 pts]

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Problem 4 (17 POINTS)

a) You are trying to synthesize chocolate in the lab. The first step is to produce theobromine ($C_7H_8N_4O_2$), a component of cacao. The reaction in the cacao plant creates theobromine and O_2 as byproducts. You have N_2, SO_2, H_2O, CO_2 available in the lab as **potential** reactants. Select your reactants and write the balanced reaction. [4 points]

b) Now you need sugar to make chocolate. Your reaction produced 2 moles of theobromine, and you have 5 moles of glucose ($C_6H_{12}O_6$) available in your lab. The recipe for chocolate calls for a 3:1 ratio of theobromine to glucose **by volume**. Is theobromine or glucose limiting, and how many cm^3 of the chocolate mixture can you produce? [10 points]

Density of theobromine: 1.52 g/cm^3 at room temperature
Density of glucose: 1.54 g/cm^3 at room temperature

c) Chocolate by itself it fine, but you conclude that the ultimate form of chocolate is chocolate-covered strawberries. It takes 0.5 cm^3 of melted chocolate to cover an average strawberry. Now using the chocolate you made in part b, how many **moles of strawberries** could you cover in chocolate? Assume that the density change with temperature change is negligible. [3 points]

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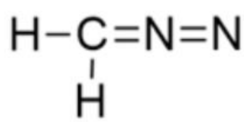
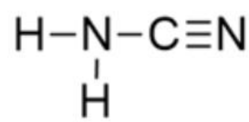
Problem 5 (23 POINTS)

a) Two structures with the formula CH_2N_2 are drawn below. Draw the missing lone pairs (where applicable) and write the formal charge on each element. [8 points]



diazomethane



cyanamide

b) Cyanamide is made industrially from calcium carbide (CaC_2), which in turn is made from calcium oxide (CaO). Write the charges on each element for calcium chloride ($CaCl_2$), sodium chloride ($NaCl$), calcium carbide (CaO), and magnesium carbide (MgO). [6 points]

NaCl	**CaO**	**MgO**
Charge on Na:	Charge on Ca:	Charge on Mg:
Charge on Cl:	Charge on O:	Charge on O:

c) Rank the compounds in terms of decreasing lattice energy. Explain in **one** sentence. [5 points]

HIGHEST ENERGY ----------------------> LOWEST ENERGY

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d) Write the Lewis structure for dichloromethane (CH_2Cl_2). [4 pts]

END OF 3.091 EXAM 1