First Hour Exam **5.111**

Write your name and your TA's name below**. Do not open the exam until the start of the exam is announced.** The exam is closed notes and closed book.

1. Read each part of each problem carefully and thoroughly.
2. Read all parts of each problem. MANY OF THE LATTER PARTS OF A PROBLEM CAN BE SOLVED WITHOUT HAVING SOLVED EARLIER PARTS. However, if you need a numerical result that you were not successful in obtaining for the computation of a latter part, make a physically reasonable approximation for that quantity (and indicate it as such) and use it to solve the latter parts.
3. A problem that requests you to "calculate" implies that several calculation steps may be necessary for the problem's solution. You must show these steps clearly and indicate all values, including physical constants used to obtain your quantitative result. **Significant figures** and **units** must be correct.
4. If you don't understand what the problem is requesting, raise your hand and a proctor will come to your desk.
5. Physical constants, formulas and a periodic table are given on the last page. You may detach this page **once the exam has started**.

1.	**PHOTOELECTRIC EFFECT**	(14 points)_____
2.	**WAVELENGTHS AND ENERGY LEVELS**	(14 points)_____
3.	**PHOTON EMISSION**	(16 points)_____
4.	**SHAPES OF ORBITALS**	(13 points)_____
5.	**MULTI-ELECTRON ATOMS**	(17 points)_____
6.	**QUANTUM NUMBERS**	(16 points)_____
7.	**LIMITING REACTANT**	(10 points)_____
	Total (100 points)	_____

Name _____**ANSWER KEY**_____

TA _____

1. PHOTOELECTRIC EFFECT (14 points)
Electrons with a kinetic energy of 4.01×10^{-19} J are ejected from the surface of a metal plate upon irradiation by a light source with a wavelength of 171 nm and an intensity of 359 Watts.

(a) (8 points) Calculate the **workfunction** of the metal.

$\phi = 7.6 \times 10^{-19}$ J

(b) (6 points) Circle the correct answer. Increasing the **intensity** of this light will

(i) (increase decrease leave unchanged) the kinetic energy of the ejected electrons

(ii) (increase decrease leave unchanged) the incident energy needed to eject electrons

(ii) (increase decrease leave unchanged) the number of electrons ejected

2. WAVELENGTHS AND ENERGY LEVELS (14 points)

A free electron is traveling at 4.0×10^{6} m/s.

(**a**) (4 points) Calculate the wavelength of this free electron.

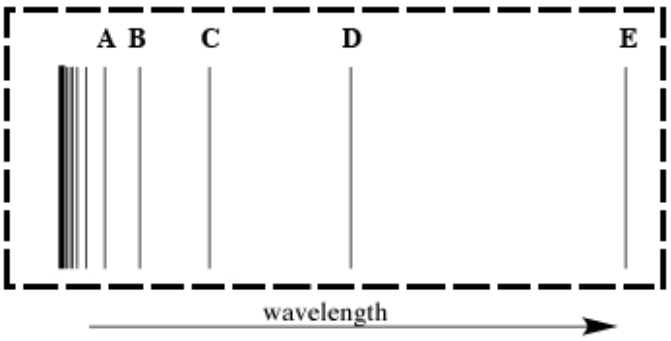
$\lambda = 1.8 \times 10^{-10}$ m or 180 nm or 1.8 Å

(b) (10 points) Now suppose that this free electron is captured by an ion. Calculate the change in energy for this electron from its free state, in which it is traveling at 4.0×10^{6} m/s, to its captured state, in which it is stably bound in the 1s orbital of a He^{+} ion.

$\Delta E = -16.0 \times 10^{-18}$ J or -1.60×10^{-17} J

3. PHOTON EMISSION (16 points)

The figure to the right represents the emission spectrum for a one-electron atom in the gas phase. All of the lines shown result from electronic transitions from excited states to the n = 3 state.



(a) (6 points) State the electron transitions that corresponds to lines:

(i) A 8 -> 3

(ii) C 6 -> 3

(iii) D 5 -> 3

(b) (10 points) If the wavelength of line D is 142. nm, calculate the wavelength of line C to 3 significant figures.

$\lambda = 1.21 \times 10^{-7}$ m or 121 nm

4. SHAPES OF ORBITALS (13 points)

Answer the following questions for 3s, 3p, and 3d orbitals

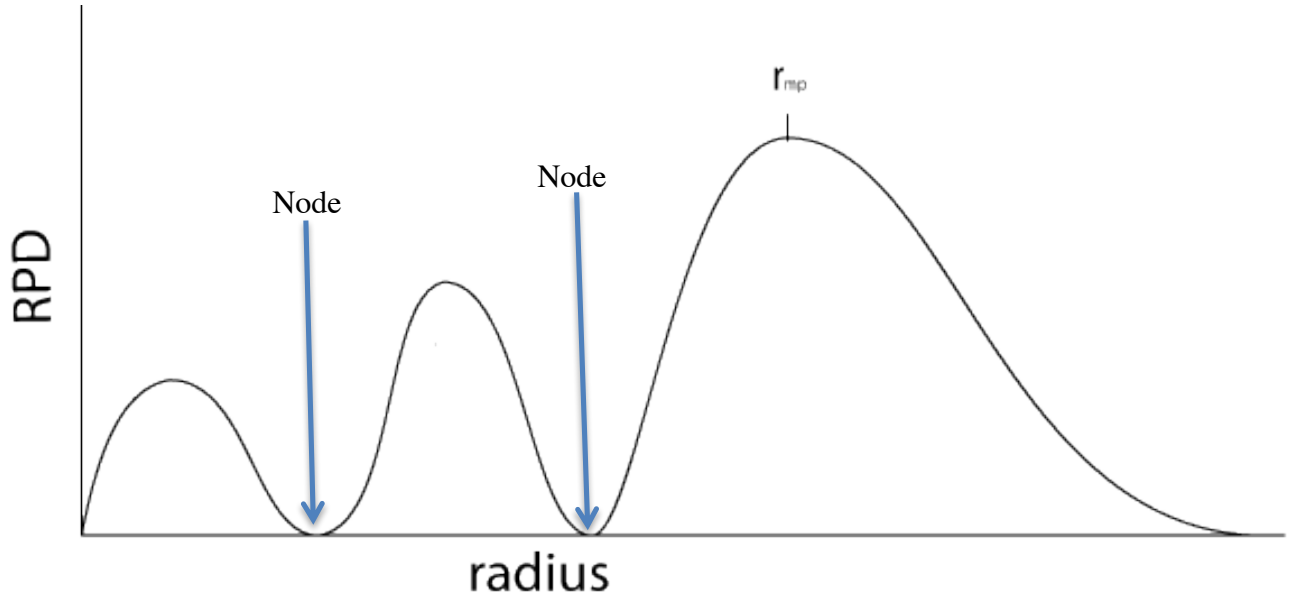
(a) (3 points) Which of these three orbitals has the highest number of angular nodes?

d, $l = 2$

(c) (3 points) Which of these three orbitals has the largest r_{mp}?

3s

(d) (7 points) Draw the radial probability distribution (RPD) for the electron in a 3s orbital. Label axes, any nodes, and the r_{mp}.



5. MULTI-ELECTRON ATOMS (17 points)

(a) (9 points) For a 2s electron of Li that has an ionization energy of 8.64×10^{-19} J, answer the following:

(i) (5 points) Calculate the Z_{eff}.

$Z_{eff} = 1.26$

(ii) (4 points) State whether the Z_{eff} value calculated above indicates that this 2s electron is being shielded. Briefly explain your answer.

It does indicate shielding, since 1.26 < 3. If there was no shielding, the electron would feel the full force of positive charge of the nucleus, and Zeff = Z = 3.

(b) (8 points) Write the electron configurations for the following atoms/ion. *You may use the noble gas configurations as a means to abbreviate the full configurations.*

(i) Co^{+2} **$[Ar]\ 3d^7$**

(ii) Os **$[Xe]6s^2 4f^{14} 5d^6$**

6. QUANTUM NUMBERS (16 points)

Circle the correct answer to indicate whether the following sets of quantum numbers are allowed or are not allowed.

For each set that is not allowed, briefly explain why it is not allowed.

For each set that is allowed, identify the orbital in terms of **n** and **l** and $\mathbf{m}_l$ values.

(a) $n = 3, l = 3, m_l = 0$ (allowed not allowed)

Explanation/orbital type: *l* can't be bigger than n-1

(b) $n = 2, l = 1, m_l = 0$ (allowed not allowed)

Explanation/orbital type: $2p_z$

(c) $n = 4, l = 0, m_l = 0$ (allowed not allowed)

Explanation/orbital type: 4s

(d) $n = 3, l = 1, m_l = 2$ (allowed not allowed)

Explanation/orbital type: biggest value allowed for m_l when *l* = 1 is +1 (m^l = -*l* …..0……+*l*)

7. LIMITING REACTANT (10 points)
Calcium carbide, CaC_2, reacts with water to form calcium hydroxide and acetylene (C_2H_2):

$$CaC_2\ (s)\ +\ 2\ H_2O\ (l)\ \ \rightarrow\ \ Ca(OH)_2\ (aq)\ +\ C_2H_2\ (g)$$

(a) (6 points) Determine which reactant is limiting when 20. g of water reacts with 50. g of calcium carbide. (Show your work to receive credit).

H_2O is limiting

(b) (4 points) Calculate the mass of C_2H_2 that will be produced, assuming a complete 100.% yield.

14. g

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