Practice Exam A Answer Key for Fall 2014

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 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**.

	Suggested time	
1.	8 minutes	(16 points)
2.	16 minutes	(30 points)
3.	14 minutes	(28 points)
4.	12 minutes	(26 points)

Total (100 points) ________________

Name ________________________________

TA _____Answer Key_____

1. (16 points) **Photoelectric effect**
(a) (8 points) The workfunction for chromium metal is 4.37 eV.
(i) Calculate the **frequency** of light required to eject electrons with a kinetic energy of 0.66 eV.

E of incident light = $4.3\underline{7}$ eV + $0.6\underline{6}$ eV = $5.0\underline{3}$ eV

E of incident light = (5.03 eV)(1.6022×10^{-19} J) = $8.0\underline{5}9 \times 10^{-19}$ J

$E = h\nu$

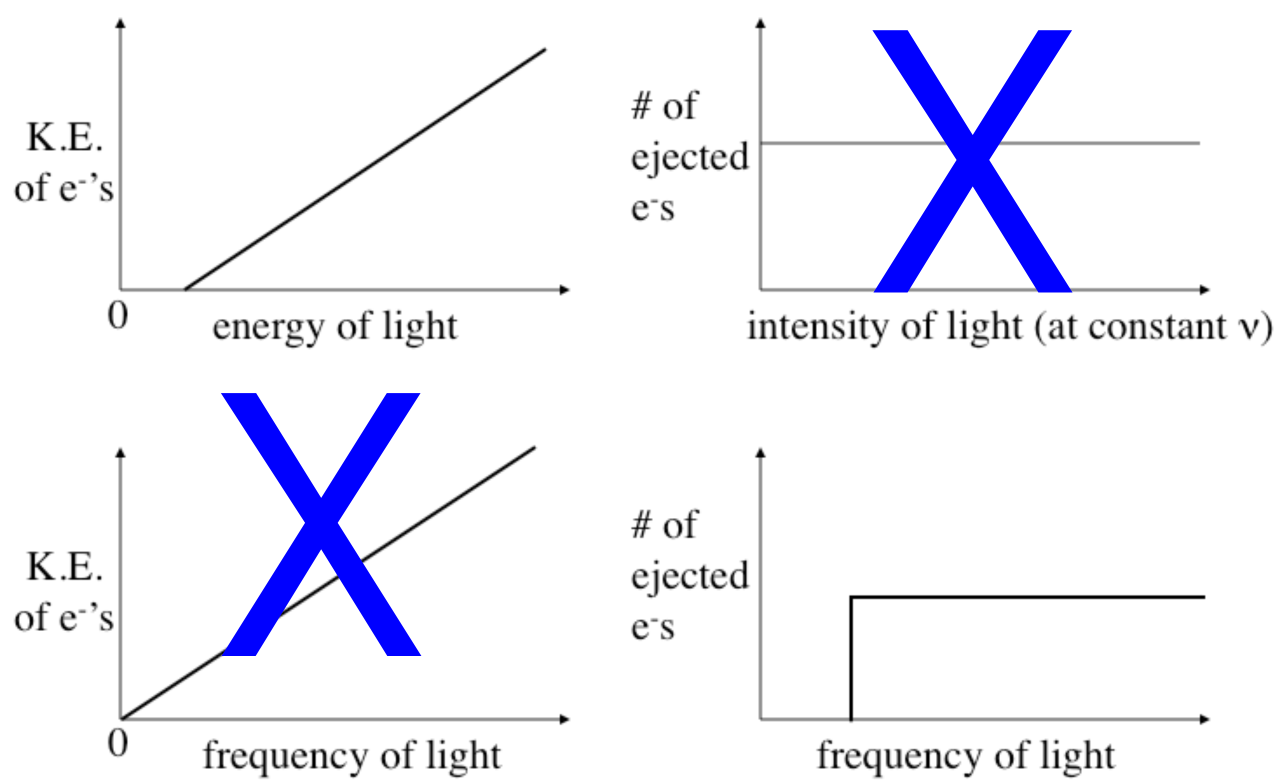
$\nu = E/h = (8.0\underline{5}9 \times 10^{-19}\ \text{J})/(6.6261 \times 10^{-34}\ \text{Js})$

$\boldsymbol{\nu = 1.22 \times 10^{15}}$ **Hz (or s^{-1})**

(ii) Is the frequency calculated in part (i) a **minimum** or a **maximum** frequency requirement for an electron to be ejected with at least 0.66 eV?

minimum

(b) (8 points) Put an **X** through any of the graphs below that incorrectly depict the relationship between the incident light and the electrons (e^-'s) ejected from the surface of a metal in the photoelectric effect.



2. (20 points) **Binding energies and transitions**

For the B^{4+} ion

(a) (12 points) Calculate the **binding energy** to three significant figures of an electron for the **(i)** ground state and **(ii)** second excited state. **(iii)** Calculate the energy difference between these two states.

$E_n = -Z^2R_H / n^2$

i) ground state → n=1

$E_1 = -5^2(2.1799 \times 10^{-18}\ J)/1^2$

$\mathbf{E_1 = -5.45 \times 10^{-17}\ J}$

ii) second excited state → n=3

$E_3 = -5^2(2.1799 \times 10^{-18}\ J)/3^2$

$\mathbf{E_3 = -6.06 \times 10^{-18}\ J}$

iii) $\Delta E = E_3 - E_1$

$\Delta E = (-6.06 \times 10^{-18}\ J) - (-5.45 \times 10^{-17}\ J)$

$\mathbf{\Delta E = 4.84 \times 10^{-17}\ J}$

(**b**) (4 points) If an electron falls from the n=3 to n=1 state, calculate the wavelength of light emitted.

From part iii above, $\Delta E = 4.84 \times 10^{-17}$ J

$E = hc / \lambda$

$4.84 \times 10^{-17}\ J = (6.626 \times 10^{-34}\ Js)(2.9979 \times 10^{8}\ m/s) / \lambda$

$\mathbf{\lambda = 4.10 \times 10^{-9}\ m}$

(c) (4 points) Without doing any calculations, would you expect that an electron in the ground state of Li^{2+} is bound more tightly or less tightly than an electron in the ground state of B^{4+}. Explain your answer.

The electron in Li^{2+} should be bound less tightly because B^{4+} has more protons, therefore, the nucleus of B^{4+} will more strongly attract its electron.

3. (10 points) **Waves**

Calculate the wavelength of an electron that has a kinetic energy of 1.5×10^{-18} J.

K.E. = $\frac{1}{2}mv^2$

1.5×10^{-18} J = $\frac{1}{2}(9.109 \times 10^{-31}$ kg$)(v^2)$

v=$1.\underline{8}1 \times 10^6$ m/s

$\lambda = h/p = h/mv$

$\lambda = (6.626 \times 10^{-34}$ Js$)/[(9.109 \times 10^{-31}$ kg$)(1.\underline{8}1 \times 10^6$ m/s$)]$

$\lambda = 4.0 \times 10^{-10}$ m

4. (20 points) **Multi-electron atoms**

(**a**) (2 points) The binding energy of a calcium 4s electron is -6.1 eV. What is the ionization energy, IE, for this 4s electron (in eV)?

6.1 eV

(**b**) (8 points) The binding energy of a calcium 2p electron is -349.7 eV. Calculate the effective nuclear charge experienced by a calcium 2p electron.

$-E_{2p} = 349.7$ eV

$-E_{2p} = (349.7 \text{ eV})(1.6022 \times 10^{-19} \text{ J/eV}) = 5.60\underline{2}9 \times 10^{-17}$ J

$-E_{nl} = [(Z_{eff})^2 R_H] / n^2$

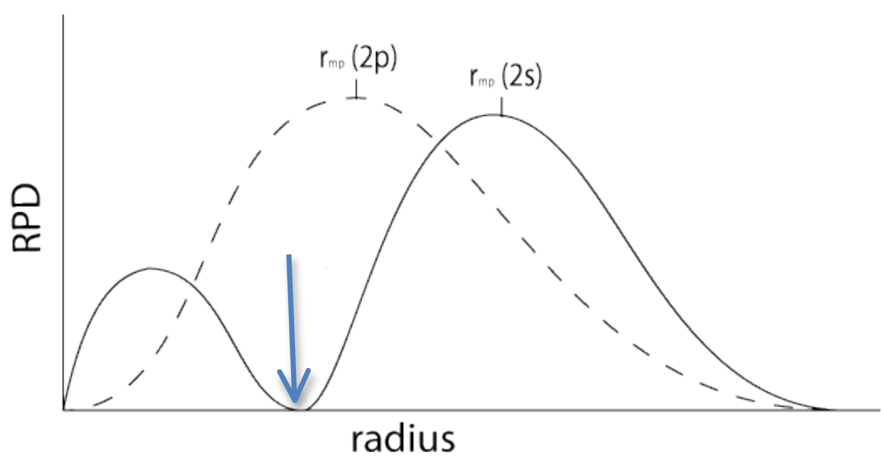
$$5.60\underline{2}9 \times 10^{-17} \text{ J} = \frac{(Z_{eff})^2 (2.18 \times 10^{-18} \text{ J})}{(2)^2}$$

$Z_{eff} = \mathbf{10.14}$

(**c**) (10 points) On the plot below,

(i) graph the radial probability distribution for a **2s orbital (as a solid line) and a 2p orbital (as a dashed line)**. Label the axes, but do not include numbers or units.

(ii) Label the r_{mp}, for each orbital, and indicate any nodes with an arrow.



(**iii**) Would a 2s electron feel more or less shielding than a 2p electron? Briefly explain your answer.

Less. The 2s electron is closer ***on average*** to the nucleus than a 2p electron (even though its most probable radius is farther than for a 2p electron).

or

Less. The 2s electron penetrates closer to the nucleus or any other reasonable explanation.

4. (16 points) **Electron configurations and quantum numbers**

(**a**) (12 points) Fill in the electron configuration expected for the following atoms or ions. *(You may use the noble gas configuration as a means to abbreviate the full configuration).*

(**ii**) Po (Z = 84)

$[Xe]6s^2 4f^{14} 5d^{10} 6p^4$

(**ii**) Ag (Z = 47)

$[Kr]5s^1 4d^{10}$

(**b**) (4 points) Determine the number of **orbitals** in a single atom that can have the following two quantum numbers:

$n = 4, m_l = -2$

If n = 4, m = -2, then *l* could be 3 or 2

2 orbitals

6. (18 points) **Balancing equations and stoichiometry**

Tristearin ($C_{57}H_{110}O_6$) can be combusted in the presence of oxygen.

$$\mathbf{2}\ C_{57}H_{110}O_6(s) + \mathbf{163}\ O_2(g) \rightarrow \mathbf{114}\ CO_2(g) + \mathbf{110}\ H_2O(l)$$

(a) (4 points) Balance the above equation for the combustion of tristearin.

(b) (7 points) What mass of water is produced from 1.00 lb (454 g) of tristearin?

$$454\ g\ C_{57}H_{110}O_6 \times \frac{1\ mol\ C_{57}H_{110}O_6}{891.44\ g\ C_{57}H_{110}O_6} \times \frac{110\ mol\ H_2O}{2\ mol\ C_{57}H_{110}O_6} \times \frac{18.02\ g\ H_2O}{1\ mol\ H_2O} = \mathbf{505\ g\ H_2O}$$

(7 points) What mass of oxygen is needed to fully react with 1.00 lb of tristearin?

$$454\ g\ C_{57}H_{110}O_6 \times \frac{1\ mol\ C_{57}H_{110}O_6}{891.44\ g\ C_{57}H_{110}O_6} \times \frac{163\ mol\ O_2}{2\ mol\ C_{57}H_{110}O_6} \times \frac{32.00\ g\ O_2}{1\ mol\ O_2} = \mathbf{1.33 \times 10^3\ g\ O_2}$$