First Hour Exam 5.111

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

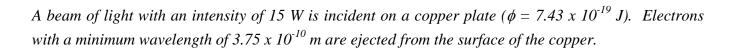
- 1. Read each part of each problem carefully and thoroughly.
- 2. Read all parts of each problem. MANY OF THE LATTER PARTS OF A PROBLEM CAN BE SOLVED WITHOUT HAVING SOLVED EARLIER PARTS. However, if you need a numerical result that you were not successful in obtaining for the computation of a latter 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.	12 minutes	(22 points)							
2.	10 minutes	(16 points)							
3.	19 minutes	(38 points)							
4.	9 minutes	(24 points)							
Total ((100 points)								
Name									

1. (22 points) The photoelectric effect

A beam of light with an intensity of 15 W is incident on a copper plate ($\phi = 7.43 \times 10^{-19} \text{ J}$). Electrons with a minimum wavelength of 3.75 x 10^{-10} m are ejected from the surface of the copper.

(a) (12 points) Calculate the frequency of the incident light.



(b) (6 points) Calculate the maximum number of electrons that can be ejected by a 3.0-second pulse of the incident light.

(c) (4 points) If a new light source ($E_i = 7.19 \times 10^{-19} \text{ J}$) with an intensity of 35 W is incident on the copper surface, what is the maximum number of electrons that can be ejected from a 6.0 second pulse of light?

2. (16	points	One-electron	atoms:
-• '	10	POILIE	One creen on	

Consider a Ca¹⁹⁺ ion with its electron in the 5th excited state.

(a) (12 points) Calculate the longest wavelength of light that could be emitted when the Ca¹⁹⁺ electron transitions to a lower energy state. Report your answer with three significant figures.

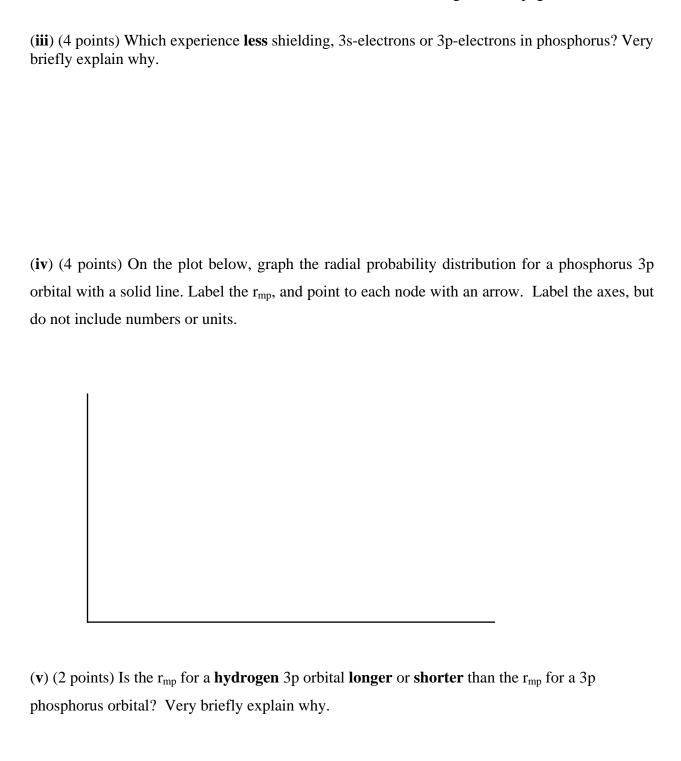
(b) (4 points) Suppose the same transition as in part (a) took place in a **hydrogen atom**. Would the wavelength of emission be longer than, shorter than, or the same as your answer to part (a). Very briefly explain why. (Note: This question does NOT require a calculation. Also, you do not need to use the answer to part (a) to answer this question.)

3. (32 points) Multi-electron atoms
(a) (16 points) An x-ray photoelectron spectroscopy experiment with an unidentified element, \mathbf{X} ,
displays an emission spectrum with four distinct kinetic energies: $5.9 \times 10^{-17} \text{ J}$, $2.53 \times 10^{-18} \text{ J}$, $2.59 \times 10^{-18} \text{ J}$
20 J, and 2.67 x 10^{-20} J. (Assume the incident light has sufficient energy to eject any electron in the
atom.)
(i) (4 points) Name all of the possible ground state atoms that could yield this spectrum.
(ii) (8 points) Calculate the binding energy of an electron in the 2p orbital of element X if the x-rays
used for the spectroscopy experiment had an energy of 2.68 x 10 ⁻¹⁶ J.
(iii) (4 points) Consider both the filled and unfilled orbitals of element X . Determine the number of:
total nodes in a 4d orbital:
angular nodes in the 2p _y orbital:
degenerate 5p orbitals:

(b)	(22	points)	The	first,	second,	and	third	ionization	energies	of	phosphorus	are	1011	kJ/mol,	1903
kJ/	/mol	and 291	12 kJ/	mol r	espective	ely.									

(i) (8 points) Calculate the effective nuclear charge (Z_{eff}) experienced by a 3p electron in phosphorus.

(ii) (4 points) Would it be expected that the minimum energy necessary to eject a 3s electron from phosphorus in a photoelectron spectroscopy experiment be **larger**, **smaller**, or **the same** as the 4^{th} ionization energy (IE₄) of phosphorus? Briefly explain your answer.



4. (24 points) Periodic trends and miscellaneous short answer

- (a) (5 points) Consider the **second** ionization energies (IE₂) for the following 3rd row elements: Si, S, Mg, Al.
 - (i) Which has the highest IE_2 ?
 - (ii) Which has the third highest IE_2 ?
- (b) (5 points) Order the following atoms and ions in order of **increasing** atomic radius: Cl, Te, Te 2 , S. Note: use the < symbol for clarity.

(c) (6 points) Give 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.)

(i) Pb
$$(Z = 82)$$

(ii) Mo
$$(Z = 42)$$

(iii)
$$Zr^+ (Z = 40)$$

(d) (4 points) In one sentence (or less!), briefly explain the physical interpretation of Ψ^2 for a hydrogen atom.
(e) (4 points) How many electrons in a single atom can have the following two quantum numbers: $n = 7$, $m_l = -3$?

Page 10 of 10 pages

 $c = 2.9979 \times 10^8 \text{ m/s}$

										$h = 6.6261 \times 10^{-34} \text{ J s}$
18 ^a VIIIA b	Noble Gases 2 He	10 Ne 20.179	Ar 39,948	36 Kr 83.80	54 Xe 131.29	86 Rn (222)				$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
VIIA		9 F 18.998 17	10	35 Br 79.904	53 1 126.904	85 At (210)			71 Lu 174.967 103 Lr (260)	$m_e = 9.1094 \times 10^{-31} \text{ kg}$
16 VIA	sla	8 O 15.999	S 32.06	34 Se 78.96	52 Te 127.60	84 Po (209)		ı	70 Yb 173.04 102 No (259)	$a_0 = 5.292 \text{ x } 10^{-11} \text{ m}$
15 VA	The Nonnetals	7 N 14.007	P 30.974	33 As 74.922	51 Sb 121.75	83 Bi 208.98		ı	69 Tm 168.934 101 Md (258)	1 amu = $1.66 \times 10^{-27} \text{ kg}$
17A IVA	The	6 C 12.011	Si 28.086	32 Ge 72.59	50 Sn 118.69	82 Pb 207.2		l	68 Er 167.26 100 Fm (257)	$\lambda = \frac{h}{p}$
13 IIIA		5 B 10.81	Al 26.982	31 Ga 69.72	100	N		l	67 Ho 164.930 99 Es (252)	$R_{\rm H} = 2.1799 \times 10^{-18} \rm J$
12 IIB			ı	30 Zn 65.38	48 Cd 112.41	80 Hg 200.59		tals	66 Dy 162.50 98 Cf (251)	$\Re = R_H/h = 3.2898 \times 10^{15} \text{ Hz}$
= B			ı	29 Cu 63.546	47 Ag 107.868	79 Au 196.966		Inner Transition Metals	65 Tb 158.925 97 Bk (247)	$E=\frac{p^2}{2m}$
10			ı	28 Ni 58.69	46 Pd 106.42	78 Pt 195.08		r Trans	64 Gd 157.25 96 Cm (247)	
9 VIIIB			ts	27 Co 58.933	45 Rh 102.906	77 Ir 192.22		Inne	63 Eu 151.96 95 Am (243)	$E_{n} = -\frac{Z^{2}R_{H}}{n^{2}}$
∞			Elemen	26 Fe 55.847	44 Ru 101.07	76 Os 190.2		ı	62 Sm 150.36 94 Pu (244)	$E_{nl} = -\frac{Z_{eff}^2 R_H}{n^2}$
7 VIIB			Transition Elements	25 Mn 54.938	43 Te (98)	75 Re 186.21		ı	60 61 Nd Pm 144.24 (145) 92 93 02 Np 238.029 237.048	$1W = 1 J s^{-1} 1 J = 1 kgm^{2}s^{-2}$
6 VIB			H	24 Cr 51.99			106 Unh (263)	ı	60 Nd 144.24 92 U 238.029	$1 \text{ eV} = 1.6022 \times 10^{-19} \text{ J}$
S VB			ı	23 V 50.942	41 Nb 92.906	73 Ta 180.948	105 Unp (262)	ı	59 Pr 140.908 91 Pa 231.036	for s wavefunction:
4 IVB			ı	22 Ti 47.88	- 5		† 104 Unq (261)		58 Ce 140.12 90 Th 232.038	$RPD = 4\pi r^2 \Psi^2 dr$
3 IIIB				21 Sc 44.956	39 Y 88.906	57 La 138.905	89 Ac 227.028		sepi	for $n_f < n_i$
2 IIA	The Active Metals 1 H Good		2	-		56 Ba 137.33	88 Ra 226.025		*Lanthanides	$v = \frac{Z^2 R_H}{h} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$
1 IA	The Me	3 Li 6.941	Na 22.990	19 K 39.098	37 Rb 85.468	55 Cs 132.905	87 Fr (223)		* +	for $n_f > n_i$
mage by M	AIT OpenCou	rseWare.								$v = \frac{Z^2 R_H}{h} \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$

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