Chem 6 sample exam 2
(100 points total)

@ This is a closed book exam to which the Honor Principle applies.

@ The last 2 pages contain equations, physical constants, and the periodic table. You can detach them for easy reference.

@ Please write clearly and SHOW YOUR WORK. If you need to write on the back of the exam paper, please indicate this clearly.

@ Some questions are more challenging than others. Allot your time accordingly, and try to answer EVERY question.

@ Please put your name on both this page and p. 2.

NAME ____

1. (9 pts) Electrons can be ejected from the surface of molybdenum metal by photons of wavelength 274 nm or less.

(a) (3 pts) Find the work function (ϕ) of molybdenum (in kJ/mol).

(b) (3 pts) Find the maximum kinetic energy (in J) of the electrons ejected from molybdenum by photons having wavelength 100 nm.

(c) (3 pts) Find the velocity (in ms^{-1}) of the electrons in part (b).

2. (10 points) Show by a calculation using the Heisenberg Uncertainty Principle that an electron **cannot** be confined within the spherical volume of a nucleus. Assume that the nuclear **radius** is 1 x 10^{-15} m and the potential energy barrier keeping the electron within the nuclear volume is ~ 1.1×10^{-12} J.

3. (10 pts) An electron can be removed from an atom using the **combined** energies of two different photons. In such an experiment, a potassium atom in the gas phase is to be ionized by two different light beams, one of which has wavelength 650 nm. [The first ionization energy for K is 418.8 kJ/mol.]

Find the maximum wavelength (in nm) for the second beam that will cause ionization.

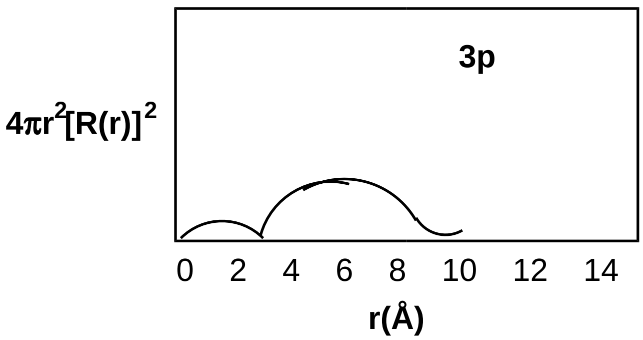
4. (12 pts) (a, 6 pts) Use the Bohr model to find the de Broglie wavelength (in nm) for an electron in the first excited state of the Be^{3+} ion.

(b, 6 pts) Use the Bohr model to consider the **velocity** of an electron in the ground state of a one-electron atom or ion. What is the effect of an increase in atomic number on this velocity? **Explain** your answer.

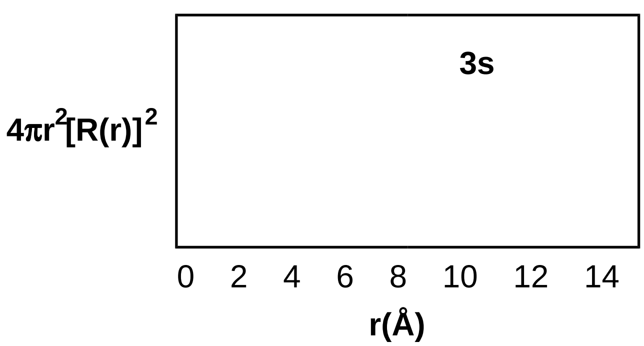
5. (12 points) For a **one-electron** atom of **unknown** atomic number Z a series of emission lines all terminate at the **second-excited level** of the atom. In this series of lines, the wavelengths of the **first** three lines are (in decreasing order): 4690 Å, 3210 Å and 2750 Å.

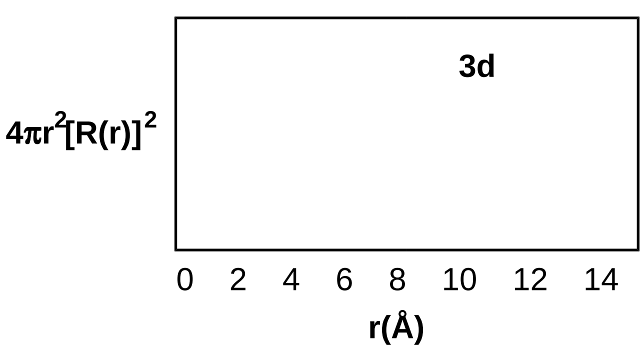
Calculate the value of the **shortest** wavelength for a line in this series. **Show your work clearly.** [You may **not** assume a value for Z -- answers which do so will receive little credit.]

6. (16 pts) (a, 6 pts) The graph below shows the radial probability distribution for the hydrogen **3p** orbital. Briefly explain the physical interpretation of the maxima and minima in the plot.



(b, 10 pts) Make your own radial probability distribution plots for the hydrogen **3s** and **3d** orbitals on the axes supplied below. Your plots should show the number of minima, the behavior of the distribution at very small and very large r, and the relative position of the maxima in comparison to those on the 3p plot.





7. (11 pts) (a, 2 pts) Give the name of the orbital with the quantum numbers n = 3, ℓ = 2.

(b, 3 pts) Give the possible m_ℓ values for this orbital.

(c, 6 pts) Sketch the **angular** part of the wavefunction corresponding to **any one** of these m_ℓ values (you don't need to specify m_ℓ). Give the **name** of the orbital, and clearly label the **axes**, the number and location of **nodes**, and, by appropriate shading, the **relative sign** of the wavefunction in different parts of your sketch.

8. (12 pts) (a, 3 pts) Circle the element with the **larger** first ionization energy:

Be Ba **Explain** your answer.

(b, 3 pts) Circle the element with the **larger** electron affinity: Te I

Explain your answer.

(c, 6 pts) Fill in the blanks below to arrange the following atoms and ions in terms of **increasing** size: K^+ Na^+ F^-

______ < _______ < _______

smallest -->largest

Explain your answer.

9. (8 pts, 2 each) Multiple choice. **Circle** your answers.

(a) The conclusion(s) from Rutherford's α-particle scattering experiment was (were):
(i) Thomson's 'plum pudding' model of the atom was correct.
(ii) The nucleus was very small in comparison to the atomic volume.
(iii) Most of the volume of the atom is occupied by the electrons.
(iv) α-particles are present in the nucleus.

(b) Pick the **true** statement(s) about the photoelectric effect.
(i) Ultraviolet photons cannot eject electrons from a metal surface. This is called the "ultraviolet catastrophe."
(ii) The more intense the light beam, the higher the energy of the emitted electrons.
(iii) The minimum frequency ν_o required to eject electrons from a metal surface is related to the work function ϕ of the metal by $\nu_o = \phi$.
(iv) The maximum kinetic energy of the emitted electrons varies linearly with the frequency of the light.

(c) Which is (are) **not** quantized?
(i) angular momentum of the electron in the Bohr atomic model
(ii) energy of a particle in a one-dimensional box
(iii) the de Broglie wavelength
(iv) photon energy

(d) Pick the set(s) of **allowed** combinations of quantum numbers for a one-electron atom.
(i) $n = 3$, $\ell = 2$, $m_\ell = 1$, $m_s = 0$
(ii) $n = 2$, $\ell = 1$, $m_\ell = 0$, $m_s = -1/2$
(iii) $n = 12$, $\ell = 2$, $m_\ell = 3$, $m_s = 1/2$
(iv) $n = -1$, $\ell = 0$, $m_\ell = 0$, $m_s = 1/2$

POSSIBLY USEFUL INFORMATION

$.E. = \frac{mv^2}{2} = \frac{p^2}{2\ m}$

$E_n = -2.18 \times 10^{-18}\ J(Z^2/n^2)$

$mvr = nh/2\pi$

$\lambda = h/p$

$\Delta E = -2.18 \times 10^{-18}\ JZ^2\ (1/n_f^2 - 1/n_i^2)$

$\nu = 3.29 \times 10^{15} s^{-1}\ Z^2(1/n_f^2 - 1/n_i^2)$

$r_n = (n^2/Z)a_o$

$(1/2)mv^2 = h\nu - \phi$

$c = 3 \times 10^8\ m\ s^{-1}$

$E = h\nu \qquad c = \nu\lambda$

$h = 6.626 \times 10^{-34}\ J\ s$

$R = 1.097 \times 10^5\ cm^{-1}$

$e = 1.60 \times 10^{-19}$ Coulombs

$1Å = 10^{-8}\ cm = 10^{-10}\ m$

$p = h/\lambda$

$a_o = 0.530Å$

$V = (4/3)\ \pi\ r^3$

1 Volt x 1 Coulomb = 1 Joule

$\Delta x \Delta p \geq \{h/4\pi\}$

1 Watt = 1 Joule/sec

$1\ nm = 10^{-9}\ m$

$N_A = 6.0 \times 10^{23}$ atoms/mol

$_n = \frac{n^2\ h^2}{8\ m\ L^2}$

$\Psi_n = A \sin(\frac{n\ \pi\ x}{L})$

$p = mv$

$k = Ae^{-Ea/RT}$

m(electron) = 9.11×10^{-31} kg

Total Energy = K.E. + P.E.

$1\ J = 1\ kg\ m^2\ s^{-2}$

$\hbar = h/2\pi$

PERIODIC TABLE

1 H 1.0079																	2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.81	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.179
11 Na 22.9898	12 Mg 24.305											13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.0983	20 Ca 40.08	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.905	54 Xe 131.29
55 Cs 132.905	56 Ba 137.33	57 La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	89 Ac 227.028	104 Unq (261)	105 Unp (262)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (266)									

58 Ce 140.12	59 Pr 140.908	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.925	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967
90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)