Chemistry 20A **Fall 2018**

Midterm (I) Wednesday, October 24

Name: [redacted] Discussion Section: 3E · 1:00 Wednesday w/ Austin

Student ID #: [redacted]

1s																	1s
H																	He
2s-filling												2p-filling					
Li	Be											B	C	N	O	F	Ne
3s-filling												3p-filling					
Na	Mg											Al	Si	P	S	Cl	Ar
4s-filling		3d-filling										4p-filling					
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5s-filling		4d-filling										5p-filling					
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6s-filling		5d-filling										6p-filling					
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7s-filling		6d-filling															
Fr	Ra	Lr	Rf	Ha	Sg	Ns	Hs	Mt	Uun	Uuu							

4f-filling													
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
5f-filling													
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No

Chemistry 20A

Fall 2018

Quiz (I) Monday, October 15

put your name here!!

Name: Discussion Section:

Student ID #:

Problem 1 (50pts.): 50

Problem 2 (50pts.): 40

Problem 3 (50pts.): ~~[illegible]~~ 50

Problem 4 (50pts.): ~~[illegible]~~ 48

Problem 5 (50pts.): 50

Problem 6 (50pts.): 50

Total Score: $\frac{288}{300} \Rightarrow 96 \Rightarrow \frac{192}{200}$

Avg. 176/200

[redacted]

1. A laser emits light of wavelength of 488nm.
   a. Calculate the frequency of the light in s^{-1}.
   b. Calculate the energy for the photon emitted in eV.
   c. The work function of Aluminum is 4.28eV. If the light from the argon ion laser is directed at the surface of a piece of aluminum, how much kinetic energy would the ejected electrons have?

(a) $488\ nm = 488 \times 10^{-9}\ m$

$c = \lambda\nu$ +5

$\nu = \frac{c}{\lambda} = \frac{2.998 \times 10^{8}\ m/s}{(488 \times 10^{-9})\ m}$ +5 $= \cancel{6.14 \times 10^{14}\ s^{-1}}\ 6.15 \times 10^{14}\ s^{-1}$ +5

(b) $\cancel{E = h\nu}$

$E = h\nu \cdot \frac{1\ eV}{1.602 \times 10^{-19}\ J}$ +5 $= (6.626 \times 10^{-34}\ J \cdot s)(6.14 \times 10^{14}\ s^{-1}) \cdot \frac{1\ eV}{1.602 \times 10^{-19}\ J}$ +5

$= 2.54\ eV$ +5

(c) $\phi = 4.28\ eV$

$E_{max} = KE = h\nu - h\nu_0 = h\nu - \phi$ +10

$= 2.54\ eV - 4.28\ eV$

$=$ negative

↓

Since $h\nu < h\nu_0$, the electrons would not have enough energy to escape the metal, so ~~KE = 0 but and~~ no electrons would be ejected. This is because the energy of the photons ~~is too low~~ is lower than ϕ.

nice!

+10

+50

[redacted]

2. Calculate the de Broglie wavelength of the following:
   a. An electron that has been accelerated to a kinetic energy of 1.8 x 10^7 J mol^{-1}
   b. a Xenon atom with a linear momentum of 7.5 x 10^{-23} kg m s^{-1}.
   c. a Neon moving at a speed of 320 m s^{-1} (Relative atomic mass of Neon: 20.18 g/mol)

+5

(a) De Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

$KE_{e^-} = \frac{1}{2} m_e v_e^2$

convert to $J/e^- = \frac{KE}{N_A}$

+5 $v_e = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2(1.8 \times 10^7 \text{ J/mol})}{(9.109 \times 10^{-31} \text{ kg})}} = 6.3$ m/s

$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})}{(9.109 \times 10^{-31} \text{ kg})(V_e \text{ from above})} = 1.2 \times 10^{-22}$ m

(b) $p = 7.5 \times 10^{-23}$ kgm/s

$\lambda = \frac{h}{p} = \frac{(6.626 \times 10^{-34} \text{ J}\cdot\text{s})}{(7.5 \times 10^{-23} \text{ kgms}^{-1})} = 8.8 \times 10^{-12}$ m +10

(c) $V = 320 \text{ ms}^{-1}$

1 atom Ne x $\frac{\text{mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{20.18 \text{ g}}{\text{mol}} \times \frac{\text{kg}}{1000 \text{ g}} = 3.351 \times 10^{-26} \frac{\text{kg}}{\text{atom}}$

+10

$\lambda = \frac{h}{mv} = \frac{(6.626 \times 10^{-34} \text{J}\cdot\text{s})}{(\text{mass from above})(320 \text{ ms}^{-1})} = 6.2 \times 10^{-11}$ m

+10

+40

3. For a hydrogen atom, radiation is emitted when a transition from n=4 to n=3 occurs.
   a. How much energy is released by the H-atom during this transition?
   b. In what region of the electromagnetic spectrum does this radiation lie? The visible: (400-760nm); ultraviolet: (100-400) nm or infrared:(760-1 0,000) nm

(a) ~~Using~~

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

So $E = h\nu = h(3.29 \times 10^{15}\ s^{-1})\, Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = \cancel{(6.626 \times 10^{-34}\ J\cdot s)(1)^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right)}$

$$= (6.626 \times 10^{-34}\ J\cdot s)(3.29 \times 10^{15}\ s^{-1})(1)^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$

$$= 1.06 \times 10^{-19}\ J$$

(b) $E = h\nu = h\left(\frac{c}{\lambda}\right)$

$$\lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34}\ J\cdot s)(2.998 \times 10^{8}\ m/s)}{(E \text{ found above})} = 1.87 \times 10^{-6}\ m$$

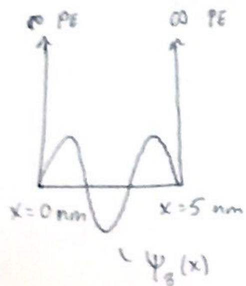
$= 1{,}870$ nm

The radiation is in the infrared region

+50

4. If there is a particle in a 1D- infinite potential square well with edges at x = 0 and x = 5 nm,
   a. Calculate the position(s) at which the particle is most and least likely to be found for the n = 3 wave function in this box?
   b. Sketch the probability density for n=3?
   c. Determine the probability of finding the particle, for the n = 3 wave function, between the first and second nodes, please carefully explain your answer?

(a)



$$\psi_3(x) = \sqrt{\frac{2}{(5\times10^{-9})}} \sin\left(\frac{3\pi x}{5\times10^{-9}}\right)$$ +5

$$\psi_3^2(x) = \frac{2}{(5\times10^{-9})} \sin^2\left(\frac{3\pi x}{5\times10^{-9}}\right)$$

The particle is most likely to be found at values of x that maximize $\psi_3^2(x)$.
It is least likely to be found at values that minimize $\psi_3^2(x)$ (~~where~~ $\cancel{\psi}$ i.e. where $\psi_3^2(x) = 0$)

So the particle is most likely to be found at values of x that satisfy $\sin^2\left(\frac{3\pi x}{5\times10^{-9}}\right) = 1$:

$$\left(\frac{3\pi x}{5\times10^{-9}}\right) = \sin^{-1}(\pm1) = \frac{\pi}{2}, \frac{3\pi}{2}, \ldots$$

$$x = \frac{(5\times10^{-9})\pi}{4\,\cancel{3\pi(2)}}, \frac{3\pi(5\times10^{-9})}{2(\cancel{3\pi})} \quad \frac{(5\times10^{-9})3}{4}$$ +2

Particle is most likely to be found at these points → $x = 8\times10^{-10}$ m and $x = 2.5\times10^{-9}$ m ✓ +2
(or 8.333×10^{-10} m unrounded) and $x = 3.8\times10^{-9}$ m should be 4.2 nm

The particle is least likely to be found at values of x that satisfy $\sin^2\left(\frac{3\pi x}{5\times10^{-9}}\right) = 0$

$$\frac{3\pi x}{5\times10^{-9}} = 0, \pi, 2\pi, 3\pi$$ +4

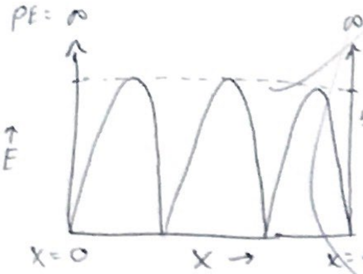
$$x = 0, \frac{5\times10^{-9}}{3}, \frac{2(5\times10^{-9})}{3}, 5\times10^{-9} \text{ m}$$

Particle is least likely to be found at these points → $x = \cancel{0}, \cancel{2\times10^{-9}\text{ m}}, \cancel{3\times10^{-9}}\text{ m}, \cancel{5\times}10^{-9}$ m

+48

Parts b & c on ~~back~~ next page

(b)



$\frac{2}{5\times10^{-9}} = 4\times10^{8}$ J ✓ +20

(c) As derived in part (a), $\Psi_3^2(x) = \frac{2}{(5\times10^{-9})}\sin^2\left(\frac{3\pi x}{5\times10^{-9}}\right)$

~~So the~~ The nodes are located at:

$x_1 = (5\times10^{-9})(\frac{1}{3})$ ✓

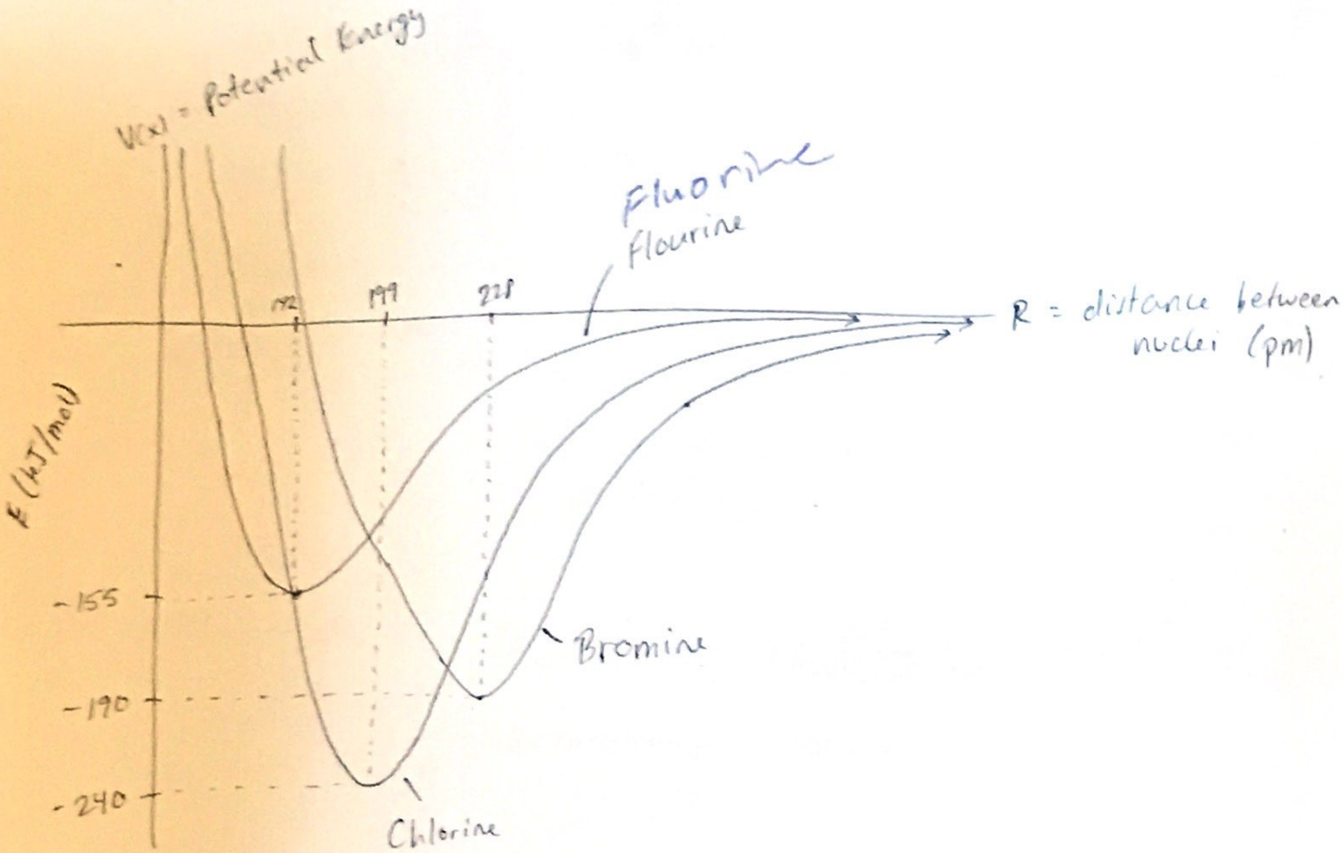
$x_2 = (5\times10^{-9})(\frac{2}{3})$

The probability of finding the particle between these 2 nodes is given by:

Probability $= \int_{x_1}^{x_2} |\Psi_3(x)|^2\,dx = \frac{1}{3}$ ✓ +18

5. Given the information below, draw a qualitative potential energy diagram for the three molecules.

Molecule	Bond Dissociation Energy (kJ/mol)	Equilibrium Bond Length (pm)
Chlorine	240	199
Bromine	190	228
Fluorine	155	142



+50

$z = 2$

6. The electron in an He^+ ion is initially at a distance 1.89 angstroms from the nucleus, and then moves to a distance 0.529 angstroms away.
   a. Calculate the magnitude of the force on the electron at each separation?
   b. Indicate the direction of the force that the proton exerts on the electron at the final separation?
   c. What is the change in kinetic energy between these positions of the electron relative to the nucleus?

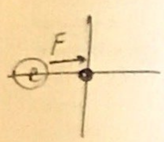
(a) At 1.89 Å :

$$|F| = \left|\frac{q_1 q_2}{4\pi\varepsilon_0 r^2}\right| = \left|\frac{(2e)(e)}{4\pi(8.854\times10^{-12})(1.89\times10^{-10}\ m)^2}\right| = \cancel{2.44\times10^{-18}\ N}\ 1.29\times10^{-8}\ N$$

At 0.529 Å :

$$|F| = \left|\frac{q_1 q_2}{4\pi\varepsilon_0 r^2}\right| = \left|\frac{2e^2}{4\pi\varepsilon_0(0.529\times10^{-10})^2}\right| = 1.65\times10^{-7}\ N$$

(b)



~~Att~~ - The force is in the positive direction with respect to the x-axis.

- The sign of the force is negative according to the equation $F = -\frac{dV}{dr}$

(c) $\Delta KE = -\Delta PE = -(PE_f - PE_i) = -\left(\frac{-2e^2}{4\pi\varepsilon_0(0.529\times10^{-10})} + \frac{2e^2}{4\pi\varepsilon_0(1.89\times10^{-10})}\right)$

$= \cancel{2.44\times10^{-18}\ J}\ 6.28\times10^{-18}\ J$

+50

Physical Constants

Avogadro's number	$N_A = 6.02214129 \times 10^{23}\ \text{mol}^{-1}$
Bohr radius	$a_0 = 0.52917721092\ \text{Å} = 5.2917721092 \times 10^{-11}\ \text{m}$
Boltzmann's constant	$k_B = 1.3806488 \times 10^{-23}\ \text{J K}^{-1}$
Electron charge magnitude	$e = 1.602176565 \times 10^{-19}\ \text{C}$
Faraday constant	$F = 96{,}485.3365\ \text{C mol}^{-1}$
Masses of fundamental particles:	
Electron	$m_e = 9.10938291 \times 10^{-31}\ \text{kg}$
Proton	$m_p = 1.672621777 \times 10^{-27}\ \text{kg}$
Neutron	$m_n = 1.674927351 \times 10^{-27}\ \text{kg}$
Permittivity of vacuum	$\epsilon_0 = 8.854187817 \times 10^{-12}\ \text{C}^2\ \text{J}^{-1}\ \text{m}^{-1}$
Planck's constant	$h = 6.62606957 \times 10^{-34}\ \text{J s}$
Ratio of proton mass to electron mass	$m_p/m_e = 1836.152672$
Speed of light in a vacuum	$c = 2.99792458 \times 10^8\ \text{m s}^{-1}$ (exactly)
Standard acceleration of terrestrial gravity	$g = 9.80665\ \text{m s}^{-2}$ (exactly)
Universal gas constant	$R = 8.3144621\ \text{J mol}^{-1}\ \text{K}^{-1}$
	$= 0.0820574\ \text{L atm mol}^{-1}\ \text{K}^{-1}$

Values are taken from the 2010 CODATA recommended values, as listed by the National Institute of Standards and Technology.

Conversion Factors

Ångström 1	$\text{Å} = 10^{-10}\ \text{m}$
Atomic mass unit	$1\ \text{u} = 1.660538921 \times 10^{-27}\ \text{kg}$
	$1\ \text{u} = 1.492417955 \times 10^{-10}\ \text{J} = 931.494061\ \text{MeV}$ (energy equivalent from $E = mc^2$)*
Calorie	$1\ \text{cal} = 4.184\ \text{J}$ (exactly)
Electron volt	$1\ \text{eV} = 1.602177 \times 10^{-19}\ \text{J}$
	$= 96.485336\ \text{kJ mol}^{-1}$
Foot	$1\ \text{ft} = 12\ \text{in} = 0.3048\ \text{m}$ (exactly)
Gallon (U.S.)	$1\ \text{gallon} = 4\ \text{quarts} = 3.785412\ \text{L}$
Liter	$1\ \text{L} = 10^{-3}\ \text{m}^3 = 10^3\ \text{cm}^3$ (exactly)
Liter-atmosphere	$1\ \text{L atm} = 101.325\ \text{J}$ (exactly)
Metric ton	$1\ \text{t} = 1000\ \text{kg}$ (exactly)
Pound	$1\ \text{lb} = 16\ \text{oz} = 0.45359237\ \text{kg}$ (exactly)
Rydberg	$1\ \text{Ry} = 2.17987217 \times 10^{-18}\ \text{J}$
	$= 1312.7498\ \text{kJ mol}$
	$= 13.60569252\ \text{eV}$
Standard atmosphere	$1\ \text{atm} = 1.01325 \times 10^5\ \text{Pa}$
	$= 1.01325 \times 10^5\ \text{kg m}^{-1}\ \text{s}^{-2}$ (exactly)
Torr	$1\ \text{torr} = 133.3224\ \text{Pa}$

*Chapter 19 uses the 2006 CODATA energy equivalent 1 u = 931 494028 MeV