Name ______________________________ Date ______________

PH 102 Exam III

General Rules: You are allowed 2 sides of an 8.5x11 in piece of paper with formulas and a calculator.

November 29, 2007
P. LeClair

Part I: Multiple choice (50%)

1. **Answer all multiple choice problems.**
2. No partial credit will be given for multiple choice questions.

1. What energy photon emitted is when an electron in a hydrogen atom goes from the $n=5$ energy level to the $n=2$? energy level?

- ◯ 10.20 eV
- ◯ 13.60 eV
- ◯ 6.80 eV
- ◯ 2.86 eV

2. Calculate the de Broglie wavelength of a 0.145 kg baseball moving at a speed of 45.2 m/s ($\approx$101 mph).

- ◯ 1.01×10^{-34} m
- ◯ 2.62×10^{-24} m
- ◯ 3.17×10^{-9} m
- ◯ 4.58×10^{-2} m

3. An inverted image of an object is viewed on a screen from the side facing a converging lens. An opaque card is then introduced covering *only the upper half* of the lens. What happens to the image on the screen?

- ◯ Half the image would disappear.
- ◯ Half the image would disappear and be dimmer.
- ◯ The entire image would appear and remain unchanged.
- ◯ The entire image would appear, but would be dimmer.

4. When $^{238}_{92}U$ decays to $^{234}_{90}Th$, what is emitted?

- ◯ beta particle
- ◯ gamma ray
- ◯ alpha particle
- ◯ deuteron

5. When an alpha particle hits a $^{39}_{19}K$ nucleus, one of the products is a proton. The other product is:

- ◯ $^{42}_{20}Ca$
- ◯ $^{36}_{18}Ar$
- ◯ $^{38}_{17}Cl$
- ◯ None of the above

6. An x-ray photon is scattered by an electron. What happens to the frequency of the *scattered photon*, relative to that of the incident photon?

◯ it increases
◯ it decreases
◯ it does not change
◯ photons cannot be scattered by electrons

7. A nonrelativistic electron and a nonrelativistic proton are moving and have the same de Broglie wavelength. Which of the following are also the same for the two particles?

◯ momentum
◯ frequency
◯ kinetic energy
◯ speed

8. A light-emitting diode (LED) emits blue photons of wavelength 480 nm. What would be the minimum voltage you would expect to apply to the LED before it emits light? (Hint: we assume all of the potential energy of one electron is converted into light.)

◯ 2.6 V
◯ 3.5 V
◯ 1.2 V
◯ 0.82 V

Part II: Problems (50%)

1. **Solve 2 problems out of the 5 below.** All problems have equal weight.
2. Clearly mark the problems you choose by filling in the adjacent circle.
3. **Show as much work as possible for partial credit.**
4. Solve the problems on separate sheets. Staple your sheets to the exam when finished.

○ **1.** Fill in the missing elements, atomic numbers, and atomic masses (denoted by question marks) in the following radioactive decay series.

$$^{228}_{90}\mathrm{Th} \xrightarrow{\alpha} {}^{224}_{?}\mathrm{Ra} \xrightarrow{\alpha} {}^{?}_{86}? \xrightarrow{\alpha} {}^{216}_{84}\mathrm{Po} \xrightarrow{\alpha} {}^{212}_{?}? \xrightarrow{\beta} {}^{212}_{83}? \xrightarrow{\beta} {}^{?}_{?}\mathrm{Po} \xrightarrow{\alpha} {}^{?}_{?}?$$

○ **2.** A hydrogen atom has a radius of $\sim 0.05\,\mathrm{nm}$. **(a)** Assuming we know the position of an electron in a hydrogen atom to an accuracy of 1% of this radius, estimate the uncertainty in the velocity of the electron. How does this value compare to c? **(b)** Compare this value to the uncertainty in the velocity of a ball of mass 0.2 kg and radius 0.05 m whose position is known within 1% of its radius.

○ **3.** A molecule is known to exist in an unstable higher energy configuration for $\Delta t = 10\,\mathrm{nsec}$, after which it relaxes to its lower energy stable state by emitting a photon. **(a)** What uncertainty in the frequency Δf of the emitted photon is implied? **(b)** If this state is being probed with Nuclear Magnetic Resonance (NMR) at a frequency of $f \approx 200\,\mathrm{MHz}$, what is the relative uncertainty in the measurement, $\Delta f/f$?

○ **4.** Calculate the binding energy *in MeV* of a deuteron (the atom $^2_1\mathrm{H}$), given that its atomic mass is 2.014102 u. Note that $m_{p^+} = 1.007825\,\mathrm{u}$, and $m_{n^0} = 1.00866\,5\mathrm{u}$.

○ **5.** In a coordination compound, the so-called "crystal field" gives rise to a difference in energy levels for some of the electrons in a transition metal ion. That is, electrons can occupy one of two states, separated by the crystal field splitting energy Δ.

The octahedral complex $[\mathrm{Cr(NH_3)_6}]^{3+}$ has a crystal field splitting of $\Delta_o \sim 2.16\,\mathrm{eV}$, while $[\mathrm{Co(NH_3)_6}]^{3+}$ has $\Delta_o \sim 2.84\,\mathrm{eV}$. What color are these compounds? Make use of the table below. If a compound absorbs a certain color of light, it exhibits the color *complementary* to the color of absorbed light.

Table 1: *Absorbed wavelength λ and observed color*

λ (nm)	absorbed color	observed color
400	violet	greenish-yellow
450	blue	yellow
490	blue-green	red
570	yellow-green	violet
580	yellow	dark blue
600	orange	blue
650	red	green

BONUS (worth 1 normal question):

1. The energy required to break one O=O bond in ozone (O_3, O=O=O) is about 500 kJ/mol. What is the maximum wavelength of the photon that has enough energy to photodissociate ozone by breaking one of the O=O bonds? You must show your work to receive bonus points. Note that Avagadro's number is $N_A = 6.02 \times 10^{23}$ things/mol.

$$O_3 \xrightarrow{hf} O + O_2$$

Useful Things

Constants:

$$\begin{aligned}
k_e &= 8.98755 \times 10^9\,\mathrm{N \cdot m^2 \cdot C^{-2}} \\
e &= 1.60218 \times 10^{-19}\,\mathrm{C} \\
c &= \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792 \times 10^8\,\mathrm{m/s} \\
h &= 6.62607 \times 10^{-34}\,\mathrm{J \cdot s} = 4.13566 \times 10^{-15}\,\mathrm{eV \cdot s} \\
\hbar &= \frac{h}{2\pi} \\
m_{e^-} &= 9.10938 \times 10^{-31}\,\mathrm{kg} = 0.510998\,\mathrm{MeV}/c^2 \\
m_{p^+} &= 1.67262 \times 10^{-27}\,\mathrm{kg} = 938.272\,\mathrm{MeV}/c^2 \\
m_{n^0} &= 1.67493 \times 10^{-27}\,\mathrm{kg} = 939.565\,\mathrm{MeV}/c^2 \\
1\,\mathrm{u} &= 931.494\,\mathrm{MeV}/c^2 \\
N_A &= 6.02214 \times 10^{23}\,\mathrm{things/mole}
\end{aligned}$$

$$\begin{aligned}
hc &= 1239.84\,\mathrm{eV \cdot nm} \\
\frac{h}{m_e c} &= 2.42631 \times 10^{-12}\,\mathrm{m}
\end{aligned}$$

Quadratic formula:

$$0 = ax^2 + bx^2 + c \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Basic Equations (non-relativistic):

$$\begin{aligned}
\vec{\mathbf{F}}_{\mathrm{net}} &= m\vec{\mathbf{a}} \text{ Newton's Second Law} \\
\vec{\mathbf{F}}_{\mathrm{centr}} &= -\frac{mv^2}{r}\hat{\mathbf{r}} \text{ Centripetal} \\
\mathrm{KE} &= (\gamma - 1)\,mc^2 \approx \frac{1}{2}mv^2 \text{ Kinetic energy} \\
\mathrm{KE}_{\mathrm{initial}} + \mathrm{PE}_{\mathrm{initial}} &= \mathrm{KE}_{\mathrm{final}} + \mathrm{PE}_{\mathrm{final}}
\end{aligned}$$

Other Things:

$$\begin{aligned}
\lambda f &= c \\
M &= \frac{h'}{h} = -\frac{q}{p} \\
\frac{1}{f} &= \frac{1}{p} + \frac{1}{q} = \frac{2}{R} \\
E_{\mathrm{photon}} &= hf = \frac{hc}{\lambda} = \frac{1239.84\,\mathrm{eV \cdot nm}}{\lambda\,(\mathrm{nm})} \\
e\Delta V &= \mathrm{KE}_{\max} = hf - \phi \\
E^2 &= p^2c^2 + m^2c^4 \\
\text{alpha particle} &= {}^4_2\alpha = {}^4_2\mathrm{He} \qquad \text{beta particle} = {}^{\ 0}_{-1}\beta = e^- \\
\text{Binding Energy} &= \left[\sum_{p^+ \& n^0} mc^2\right] - m_{\mathrm{atom}}c^2
\end{aligned}$$

$$\begin{aligned}
\lambda_{\mathrm{out}} - \lambda_{\mathrm{in}} &= \frac{h}{m_e c}(1 - \cos\theta) \\
\lambda &= \frac{h}{|\vec{\mathbf{p}}|} = \frac{h}{\gamma m v} \approx \frac{h}{mv} \\
\Delta x \Delta p &\geq \frac{h}{4\pi} \\
\Delta E \Delta t &\geq \frac{h}{4\pi} \\
E_n &= -13.6\,\mathrm{eV}/n^2 \\
E_i - E_f &= -13.6\,\mathrm{eV}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = hf \;\; \textit{Hydrogen only} \\
mvr &= n\hbar \\
v^2 &= \frac{n^2\hbar^2}{m_e^2 r^2} = \frac{k_e e^2}{m_e r}
\end{aligned}$$

Periodic Table of the Elements

1 H 1.00794																1 H 1.00794	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		118 (293)

58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
90 Th 232.0381	91 Pa 231.03588	92 U 238.0289	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 (262)

S.E. Van Bramer, 7/22/99

1995 IUPAC masses and Approved Names from http://www.chem.qmw.ac.uk/iupac/AtWt/

masses for 107-111 from C&EN, March 13, 1995, P 35

112 from http://www.gsi.de/z112e.html

114 from C&EN July 19, 1999

116 and 118 from http://www.lbl.gov/Science-Articles/Archive/elements-116-118.html