NAME:______________________________ Student Number:________________________

Fall 2012 **Chemistry 1000 Practice Midterm #1A** ____/ 69 marks

INSTRUCTIONS:
1) Please read over the test carefully before beginning. You should have 8 pages of questions and a formula/periodic table sheet.
2) If your work is not legible, it will be given a mark of zero.
3) Marks will be deducted for incorrect information added to an otherwise correct answer.
4) Marks will be deducted for improper use of significant figures and for missing or incorrect units.
5) Show your work for all calculations. Answers without supporting calculations will not be given full credit.
6) You may use a calculator.
7) You have 90 minutes to complete this test.

Confidentiality Agreement:
I agree not to discuss (or in any other way divulge) the contents of this exam until after 8:30pm Mountain Time on Monday, October 15th, 2012. I understand that breaking this agreement would constitute academic misconduct, a serious offense with serious consequences. The minimum punishment would be a mark of 0/69 on this exam and removal of the "overwrite midterm mark with final exam mark" option for my grade in this course; the maximum punishment would include expulsion from this university.

Signature: ______________________________ Date: ________________________________
Course: CHEM 1000 (General Chemistry I)
Semester: Fall 2012
The University of Lethbridge

Spelling matters!

Fluorine = F Fluorene = $C_{13}H_{10}$

Flourine =

Question Breakdown

Q1	/ 2
Q2	/ 6
Q3	/ 4
Q4	/ 8
Q5	/ 7
Q6	/ 6
Q7	/ 6
Q8	/ 2
Q9	/ 6
Q10	/ 4
Q11	/ 3
Q12	/ 5
Q13	/ 10

Total	/ 69

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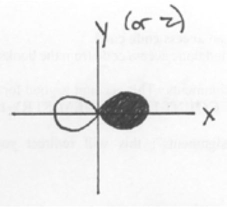
1. What is the difference between a Sievert and a Gray? **[2 marks]**

A Gray measures absorbed dose of radiation. Absorbed dose is the actual amount of energy absorbed from exposure to radiation. 1 Gray = 1 Joule per kilogram

A Sievert measures equivalent dose of radiation. Since different forms of radiation interact with biological tissue in different ways (even if the absorbed dose is the same), equivalent dose is used to measure the predicted amount of biological damage caused by exposure to radiation. It is also expressed in Joules per kilogram but 1 Gy ≠ 1 Sv.

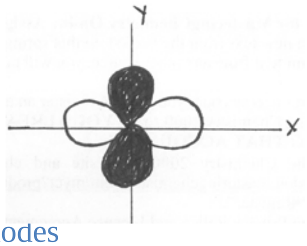
2. Sketch each of the following atomic orbitals. Clearly draw and label axes. Underneath each sketch, indicate how many planar nodes the orbital has.
Do not show radial nodes. **[6 marks]**

(a) $4p_x$



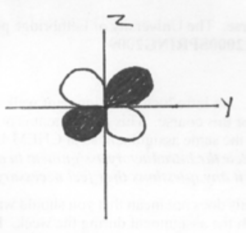
1 planar node

(b) $4d_{x^2-y^2}$



2 planar nodes

(c) $4d_{yz}$



2 planar nodes

Make sure you show the correct phases!
**Many* people drew radial nodes even though you were specifically asked not to.*
Please make sure to follow the instructions.

3. Complete the following table.
Make sure your symbol is formatted in the same way as the example. **[4 marks]**

Symbol	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons
$^{209}_{83}\mathrm{Bi}^{3+}$	83	209	83	126	80
$\boxed{^{115}_{49}\mathrm{In}^{3+}}$	49	115	49	66	46

*Mass number is *not* the average mass given on the periodic table. It's #protons+#neutrons. Note relationship between charge, #protons and #electrons.*

4. Carbon-14 decays to nitrogen-14. **[8 marks]**

(a) What kind of nuclear reaction is this? *[1 mark]*

beta emission (or beta decay)

(b) Calculate the energy change when a single atom of carbon-14 decays. *[5 marks]*

Step 1: Write a balanced chemical equation (which you needed for part (a) anyway)

$$\boxed{{}^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta}$$

Step 2: Calculate the mass change for this equation.

Note that the electron emitted (β particle) will be replaced by an electron as, technically, ${}^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}N^{+} + {}^{0}_{-1}\beta \rightarrow {}^{14}_{7}N$. *So, we do not include the mass of the electron.*

$$\boxed{\begin{aligned} \Delta \mathrm{m} &= \mathrm{m}_{\text{products}} - \mathrm{m}_{\text{reactants}} \\ &= (14.003074005u) - (14.003241988u) \\ \Delta \mathrm{m} &= -0.000167983u \end{aligned}}$$

9 decimal places therefore 6 sig. fig.

$$\boxed{\begin{aligned} \Delta \mathrm{m} &= -0.000167983u \times \frac{1.660539 \times 10^{-27}\,kg}{1u} \\ \Delta \mathrm{m} &= -2.78942 \times 10^{-31}\,kg \end{aligned}}$$

6 sig. fig.

Step 3: Calculate the energy change for this equation

$$\boxed{\begin{aligned} \Delta \mathrm{E} &= \Delta \mathrm{mc}^2 \\ &= \left(-2.78942 \times 10^{-31}\,kg\right)\left(2.997925 \times 10^{8}\,\tfrac{m}{s}\right)^2 \\ &= -2.50701 \times 10^{-14}\,\tfrac{kg \cdot m^2}{s^s} \\ \Delta \mathrm{E} &= -2.50701 \times 10^{-14}\,J \end{aligned}}$$

6 sig. fig.

(c) Calculate the energy change when one mole of carbon-14 decays. *[2 marks]*

There are Avogadro's number of atoms in one mole, so multiply the energy for a single decay by Avogadro's number.

$$\boxed{\begin{aligned} \Delta \mathrm{E} &= \left(-2.50701 \times 10^{-14}\,\tfrac{J}{atom}\right)\left(6.022141 \times 10^{23}\,\tfrac{atoms}{mol}\right) \\ \Delta \mathrm{E} &= -1.50976 \times 10^{10}\,\tfrac{J}{mol} \end{aligned}}$$

6 sig. fig.

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5. A graph of the band of stability appears on the data sheet. **[7 marks]**

(a) Define the term “half-life”. *[1 mark]*

A half-life is the time required for half of a sample of radioactive material to decay.

More generally, a half-life is the time required for half of any sample to react.

(b) What is the significance of the Z=N line? *[1 mark]*

The Z = N line indicates which isotopes would have equal numbers of protons and neutrons. For elements with fewer than 20 protons, the most stable isotopes have Z ≈ N.

(c) Why does the band of stability diverge from the Z=N line? *[2 marks]*

Elements with heavier nuclei are only stable if N > Z since they require more neutrons to reduce the electromagnetic repulsions between protons within the nucleus.

The nucleus is held together by the strong nuclear force (which decays rapidly as distance between nucleons increases). If the number of protons is held constant, increasing the number of neutrons increases the number of nucleons participating in the strong nuclear force.

Therefore, having N > Z both increases the effect of the strong nuclear force and decreases the effect of electromagnetic repulsions.

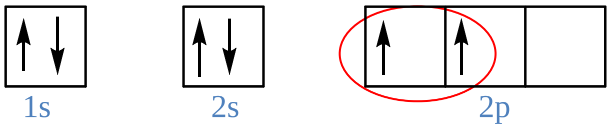
(d) What kind of decay would you expect $^{242}_{99}\text{Es}$ to undergo? Briefly, justify your answer. *[3 marks]*

^{242}Es has Z = 99 and N = 143.

There are no stable isotopes of Es (Einsteinium) as it contains too many protons. Such a large isotope is most likely to undergo either alpha emission (to raise N/Z) or beta emission (to reduce N/Z).

^{242}Es is at the bottom of the band of isotopes that exist. It will therefore undergo nuclear reaction to raise N/Z. As such, it is predicted to undergo alpha emission.

6. Consider the following orbital occupancy diagram, drawn in haste by a student who was running late. It was intended to show all core and valence electrons for a neutral atom. **[6 marks]**



(a) Label the boxes to indicate which subshell each box (or set of boxes) represents.
1 mark for having all three labels *[1 mark]*

(b) Identify the neutral element represented by this diagram. *[1 mark]*
carbon (C)

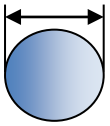
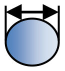
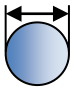
(c) In the space below, write a valid set of four quantum numbers for each of the two circled electrons. *[4 marks]*

electron on left: $n = 2$, $\ell = 1$, $m_\ell = -1$, 0 or $+1$, $m_s = +½$ or $-½$

electron on right: $n = 2$, $\ell = 1$, $m_\ell = -1$, 0 or $+1$ but different from above, m_s = same as above

BOTH electrons had to have valid values to get the mark as that was what showed that you understood what the quantum number indicated

7. Three kinds of particles were found when analyzing a piece of rusting iron. They are suspected to be Fe, Fe^{2+} and Fe^{3+}. Their sizes were measured and listed in the table below. Complete the table with the appropriate symbol and electron configuration *(in line notation)* for each particle. Also, circle the corresponding magnetic behavior expected for that particle. **[6 marks]**

Size of the particle	Symbol	Electron Configuration (Noble Gas Abbreviation)	Magnetic Property
248 pm 	Fe	[Ar] $4s^2$ $3d^6$	[✓ Paramagnetic] Diamagnetic
130 pm 	Fe^{3+}	[Ar] $3d^5$	[✓ Paramagnetic] Diamagnetic
154 pm 	Fe^{2+}	[Ar] $3d^6$	[✓ Paramagnetic] Diamagnetic

Electron configurations were marked based on the symbol next to them (assuming it was one of the permitted options).

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8. Heisenberg's Uncertainty Principle states that the more precisely we know one property of certain particles, the less precisely we know a different property (and vice versa). What are the two properties referred to by Heisenberg's Uncertainty Principle? **[2 marks]**

position and momentum

9. What observations regarding the photoelectric effect are impossible to explain using classical physics? Briefly explain the difficulties from the perspective of classical physics. **[6 marks]**

- For any given metal, there is a minimum frequency below which no photoelectric effect is observed. Classically, the frequency is unrelated to the energy of a wave. Rather, the amplitude (intensity) controls the energy of the wave. Increasing the intensity at fixed wavelength should eventually provide enough energy to eject electrons.

- The kinetic energies of the ejected electrons increases linearly with frequency. The problem is essentially the same as above. Classically, it's not clear why the frequency matters.

- Increasing the intensity increases the number of ejected electrons (i.e. the current), not their energies. One can imagine that increasing the energy of a wave might increase the current generated, but classically we would expect the energies of the ejected electrons to also depend on the intensity.

10. Which of the following sets of quantum numbers could belong to an electron in a ground state atom of manganese (Mn)? **[4 marks]**

- For each set of quantum numbers describing one of the electrons in ground state manganese, name the orbital that electron is in.
- For each set of quantum numbers *not* describing one of the electrons in ground state manganese, **briefly** indicate why not.

(a) $n = 1$, $l = 1$, $m_l = 0$, $m_s = +½$

No electron. l must be less than n

(b) $n = 3$, $l = 0$, $m_l = 0$, $m_s = +½$

3*s*

(c) $n = 3$, $l = 2$, $m_l = -1$, $m_s = +½$

3*d*

(d) $n = 4$, $l = 1$, $m_l = 1$, $m_s = +½$

No electron. There are no 4p electrons in a ground state atom of manganese.

Many people assumed that Mn only had 3d electrons. It has electrons in all orbitals up to 3d.

11. **[3 marks]**

(a) Give the complete electron configuration for arsenic (As).
Do not use the noble gas abbreviation. *[1 mark]*

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^3$

(b) What monoatomic ion would you expect arsenic to form? **Briefly**, justify your answer. *[2 marks]*

As^{3-}

As^{3-} will have the same electron configuration as the closest noble gas (Kr)

No credit for saying that arsenic turns into krypton. Krypton has three more protons than As^{3-}.

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12. Potassium (K) exists as a mixture of three isotopes:

Percent Abundance	Mass of Isotope
93.258%	38.96371 u
0.0012%	39.96400 u

Complete the table by calculating the percent abundance and mass of the third isotope of potassium. *Show your work in the space below.* **[5 marks]**

$$\boxed{\% = 100\% - (93.258\% + 0.0012\%) = 6.741\%}$$

$$\boxed{\mathrm{M}_{\mathrm{av}} = 39.0983u}$$

$$\boxed{\mathrm{M}_{\mathrm{av}} = \left(\frac{93.258\%}{100\%} \times 38.96371u\right) + \left(\frac{0.0012\%}{100\%} \times 39.96400u\right) + \left(\frac{6.741\%}{100\%} \times M_{??}\right)}$$

$$\boxed{\begin{aligned}
&39.0983u = \left(\frac{93.258\%}{100\%} \times 38.96371u\right) + \left(\frac{0.0012\%}{100\%} \times 39.96400u\right) + \left(\frac{6.741\%}{100\%} \times M_{??}\right) \\
&39.0983u = 36.337u + 0.00048u + \left(\frac{6.741\%}{100\%} \times M_{??}\right) \\
&2.761u = \left(\frac{6.741\%}{100\%} \times M_{??}\right) \\
&M_{??} = \frac{2.761u}{0.06741} \\
&M_{??} = 40.96u
\end{aligned}}$$

13. An ultraviolet lamp produces electromagnetic radiation with a wavelength of 150. nm. **[10 marks]**

(a) Calculate the energy of one photon from this ultraviolet lamp. *[3 marks]*

$$\boxed{\begin{aligned}
&c = \nu\lambda \\
&\nu = \frac{c}{\lambda} = \frac{2.997925\times10^{8}\,\frac{m}{s}}{150.nm}\times\frac{10^{9}\,nm}{1m} = 2.00\times10^{15}\,\frac{1}{s} = 2.00\times10^{15}\,Hz \\
&E = h\nu = \left(6.626070\times10^{-34}\,\frac{J}{Hz}\right)\times\left(2.00\times10^{15}\,Hz\right) = 1.32\times10^{-18}\,J
\end{aligned}}$$

The two steps may be combined using $E=hc/\lambda$

(b) Would the radiation from this ultraviolet lamp be capable of ionizing the last electron out of a ground state Li^{2+} ion?
Your answer must be backed up by calculations. No credit will be given for answers that are strictly 'yes' or 'no'. *[7 marks]*

$$\boxed{Z = 3}$$

$$\boxed{n_{initial} = 1}$$

$$\boxed{n_{final} = \infty} \text{ and/or } \boxed{E_{final} = 0J}$$

$$\boxed{\begin{aligned}
&\Delta E = E_{final} - E_{initial} \\
&\Delta E = \left(-R_H\frac{Z^2}{n_{final}^2}\right) - \left(-R_H\frac{Z^2}{n_{initial}^2}\right) \\
&\Delta E = \left(-R_H\frac{3^2}{\infty^2}\right) - \left(-R_H\frac{3^2}{1^2}\right) \\
&\Delta E = (0J) - (-9R_H) \\
&\Delta E = 9R_H = 9\times\left(2.179872\times10^{-18}\,J\right) = 1.961885\times10^{-17}\,J
\end{aligned}}$$

This is a higher energy than the energy of one photon from the UV lamp.
As such, the UV lamp is NOT capable of ionizing the last electron out of a ground state lithium atom.

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Some Useful Constants and Formulae

Fundamental Constants and Conversion Factors

Atomic mass unit (u)	$1.660\ 539 \times 10^{-27}$ kg	Planck's constant	$6.626\ 070 \times 10^{-34}$ J·Hz^{-1}
Avogadro's number	$6.022\ 141 \times 10^{23}$ mol^{-1}	Proton mass	1.007 277 u
Bohr radius (a_0)	$5.291\ 772 \times 10^{-11}$ m	Neutron mass	1.008 665 u
Electron charge (e)	$1.602\ 177 \times 10^{-19}$ C	Rydberg Constant (R_H)	$2.179\ 872 \times 10^{-18}$ J
Electron mass	$5.485\ 799 \times 10^{-4}$ u	Speed of light in vacuum	$2.997\ 925 \times 10^{8}$ m·s^{-1}

Formulae

$$c = \nu\lambda \qquad E = h\nu \qquad p = mv \qquad \lambda = \frac{h}{p} \qquad \Delta x \cdot \Delta p > \frac{h}{4\pi}$$

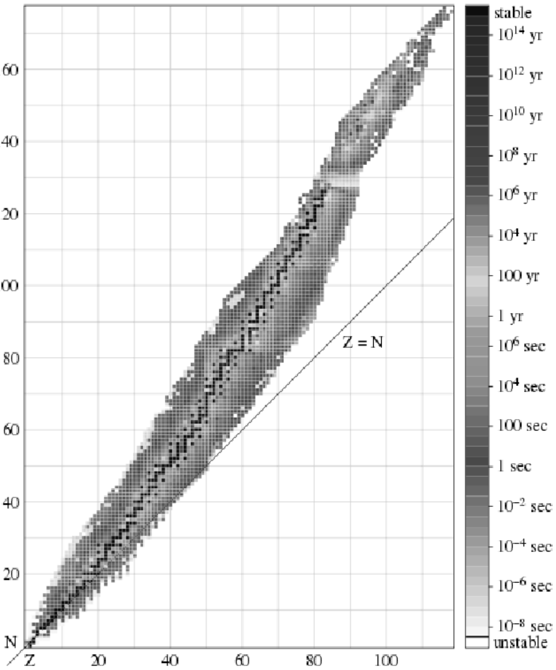
$$r_n = a_0 \frac{n^2}{Z} \qquad E_n = -R_H \frac{Z^2}{n^2} \qquad E_k = \frac{1}{2} m v^2$$

$$\Delta E = \Delta m c^2 \qquad A = -\frac{\Delta N}{\Delta t} \qquad A = kN \qquad \ln\left(\frac{N_2}{N_1}\right) = -k(t_2 - t_1) \qquad \ln(2) = k \cdot t_{1/2}$$

Some Useful Masses

$^{14}_{6}C$	14.003 241 988 u
$^{14}_{7}N$	14.003 074 005 u
$^{4}_{2}\alpha$	4.001 506 179 u
$^{1}_{1}p$	1.007 276 467 u
$^{1}_{0}n$	1.008 664 916 u

Band of Stability Graph



The graph at the right shows the band of stability. Stable isotopes are in black. Isotopes that exist but are not stable are shown in varying shades of gray with the shades of gray corresponding to different half-lives.

The original version of the graph used a rainbow colour scale.
http://commons.wikimedia.org/wiki/File:Isotopes_and_half-life_eo.svg

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CHEM 1000 Periodic Table

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.0079 **H** 1																	4.0026 **He** 2
6.941 **Li** 3	9.0122 **Be** 4											10.811 **B** 5	12.011 **C** 6	14.0067 **N** 7	15.9994 **O** 8	18.9984 **F** 9	20.1797 **Ne** 10
22.9898 **Na** 11	24.3050 **Mg** 12											26.9815 **Al** 13	28.0855 **Si** 14	30.9738 **P** 15	32.066 **S** 16	35.4527 **Cl** 17	39.948 **Ar** 18
39.0983 **K** 19	40.078 **Ca** 20	44.9559 **Sc** 21	47.88 **Ti** 22	50.9415 **V** 23	51.9961 **Cr** 24	54.9380 **Mn** 25	55.847 **Fe** 26	58.9332 **Co** 27	58.693 **Ni** 28	63.546 **Cu** 29	65.39 **Zn** 30	69.723 **Ga** 31	72.61 **Ge** 32	74.9216 **As** 33	78.96 **Se** 34	79.904 **Br** 35	83.80 **Kr** 36
85.4678 **Rb** 37	87.62 **Sr** 38	88.9059 **Y** 39	91.224 **Zr** 40	92.9064 **Nb** 41	95.94 **Mo** 42	(98) **Tc** 43	101.07 **Ru** 44	102.906 **Rh** 45	106.42 **Pd** 46	107.868 **Ag** 47	112.411 **Cd** 48	114.82 **In** 49	118.710 **Sn** 50	121.757 **Sb** 51	127.60 **Te** 52	126.905 **I** 53	131.29 **Xe** 54
132.905 **Cs** 55	137.327 **Ba** 56	**La-Lu**	178.49 **Hf** 72	180.948 **Ta** 73	183.85 **W** 74	186.207 **Re** 75	190.2 **Os** 76	192.22 **Ir** 77	195.08 **Pt** 78	196.967 **Au** 79	200.59 **Hg** 80	204.383 **Tl** 81	207.19 **Pb** 82	208.980 **Bi** 83	(210) **Po** 84	(210) **At** 85	(222) **Rn** 86
(223) **Fr** 87	226.025 **Ra** 88	**Ac-Lr**	(261) **Rf** 104	(262) **Db** 105	(263) **Sg** 106	(262) **Bh** 107	(265) **Hs** 108	(266) **Mt** 109	(281) **Dt** 110	(283) **Rg** 111							

138.906 **La** 57	140.115 **Ce** 58	140.908 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.965 **Eu** 63	157.25 **Gd** 64	158.925 **Tb** 65	162.50 **Dy** 66	164.930 **Ho** 67	167.26 **Er** 68	168.934 **Tm** 69	173.04 **Yb** 70	174.967 **Lu** 71
227.028 **Ac** 89	232.038 **Th** 90	231.036 **Pa** 91	238.029 **U** 92	237.048 **Np** 93	(240) **Pu** 94	(243) **Am** 95	(247) **Cm** 96	(247) **Bk** 97	(251) **Cf** 98	(252) **Es** 99	(257) **Fm** 100	(258) **Md** 101	(259) **No** 102	(260) **Lr** 103

Developed by Prof. R. T. Boeré