NAME:_____ Student Number:_____

Fall 2018 **Chemistry 1000 Midterm #1A** ____/ 55 marks

INSTRUCTIONS:
1) Please read over the test carefully before beginning. You should have 6 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 test until after 8:00pm Mountain Time on Tuesday, October 16th, 2018 (i.e. 24 hours **after** you finish writing this test). I understand that breaking this agreement would constitute academic misconduct, a serious offense with serious consequences. The minimum punishment would be a mark of 0/55 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 2018
The University of Lethbridge

Spelling matters!

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

Flourine =



Question Breakdown

Q1	/ 4
Q2	/ 5
Q3	/ 6
Q4	/ 3
Q5	/ 5
Q6	/ 3
Q7	/ 7
Q8	/ 8
Q9	/ 14

Total	/ 55

NAME:_____ Student Number:_____

1. Write electron configurations for each of the following species. **[4 marks]**
Use the noble gas notation, but always show all electrons in the valence shell explicitly.

(a) N $[He]2s^2 2p^3$

(b) N^{3-} $[He]2s^2 2p^6$ *anions have more electrons than the neutral atom*

(c) Fe $[Ar]4s^2 3d^6$

(d) Fe^{3+} $[Ar]3d^5$ *cations have fewer electrons than the neutral atom; for transition metal cations, remove the s electrons first*

2. Answer the following questions about chlorine (Cl), argon (Ar) and potassium (K). **[5 marks]**

(a) List these three neutral elements in order of increasing atomic radius.

smallest radius _____Ar_____ _____Cl_____ _____K_____ largest radius

(b) List these three neutral elements in order of increasing first ionization energy (I_1).

smallest I_1 _____K_____ _____Cl_____ _____Ar_____ largest I_1

(c) List these three neutral elements in order of increasing electron affinity (E_{ea}).

smallest E_{ea} _____Ar_____ _____K_____ _____Cl_____ largest E_{ea}

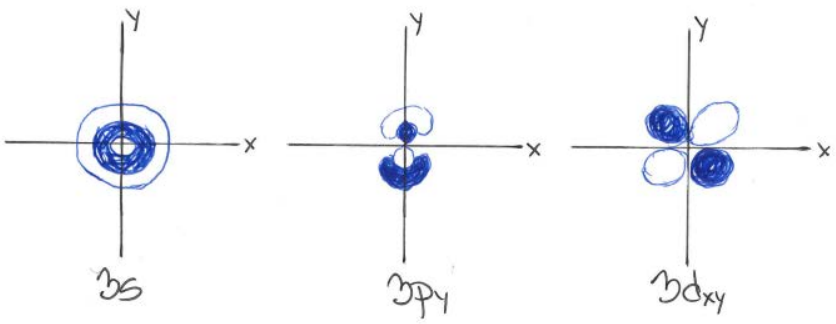
Noble gases do not have positive electron affinity.
Adding an electron to a noble gas would start a new shell of electrons (so the extra electron would be too heavily shielded from the positive charge of the nucleus).

(d) In order to be isoelectronic with argon, chlorine must become which ion? ___Cl^-___

(e) In order to be isoelectronic with argon, potassium must become which ion? ___K^+___

3. When n = 3, there are three subshells (3s, 3p, and 3*d*). Draw and label **one** orbital from each of these three subshells. Show any radial nodes. **[6 marks]**
Each orbital must be clearly named, drawn on a labeled set of axes and show relative phase. The orbital label must refer to the specific orbital (not just name the subshell).

A sample correct answer is shown below. Students could draw any of the three 3p orbitals and any of the five 3d orbitals. For full credit, the drawing had to show a specific orbital from each subshell and it had to be labeled as such (not just "3p" or "3d") drawn on a properly labeled set of axes with the correct number of radial nodes (one for 3p and two for 3s) with phases drawn correctly.



NAME:_____ Student Number:_____

4. The table below lists four quantum numbers corresponding to each orbital. There is **one** wrong number in each row. Circle the wrong number. **[3 marks]**

Orbital	***n***	***l***	m_l	m_s
7s	7	0	0	+1
6d	6	2	3	+½
5f	5	4	2	-½

5. Answer the following questions concerning the photoelectric effect. **[5 marks]**

(a) When light is applied to a piece of metal "M" in a photoelectric effect experiment, no electrons are ejected. In order to produce a positive photoelectric effect, which of the following approaches could you take as the next step? *[3 marks]*

Circle **all** the answer(s) that might work. Marks will be deducted for incorrect choices.

a. Increase the intensity of the light.

b. Decrease the intensity of the light.

c. Use light with a longer wavelength.

d. Use light with a shorter wavelength.

e. Use light of higher frequency.

f. Use light of lower frequency.

g. Replace the metal "M" with another metal that has a smaller ϕ (work function/ threshold energy/electron binding energy).

h. Replace the metal "M" with another metal that has a larger ϕ (work function/ threshold energy/electron binding energy).

(b) Use one or two sentences to summarize the contribution made by the photoelectric effect to quantum theory. *[2 marks]*

It takes a certain amount of energy to remove an electron from a metal. The minimum frequency required to remove electrons show that light is actually made of photons with energy $E = h\nu$.

Einstein's theory of the photoelectric effect therefore introduced the idea of wave-particle duality, by proposing that light is made of particles with energy E related to the frequency ν, a wave property.

NAME:_____ Student Number:_____

6. There are two naturally occurring isotopes of chlorine: ^{35}Cl and ^{37}Cl. **[3 marks]**

(a) How do atoms of ^{35}Cl and ^{37}Cl differ? Be specific. *[1 mark]*

^{37}Cl has two more neutrons than ^{35}Cl.

Yes, ^{37}Cl is heavier than ^{35}Cl. But WHY is it heavier?

(b) Which of these two isotopes is more abundant in nature? Briefly explain how that can be determined from information provided on this test (including this question and the data sheet). *[2 marks]*

^{35}Cl

The average atomic mass of Cl is 35.4527 u (see periodic table). This is closer to the mass of ^{35}Cl (35 u) than it is to the mass of ^{37}Cl (37 u). Therefore, there are more atoms of ^{35}Cl than ^{37}Cl in an average sample.

7. ^{192}Ir is often used in radiotherapy to treat certain cancers in the head, as well as some breast cancers. **[7 marks]**

^{192}Ir beta decays, producing an electron with a momentum of 8.376×10^{-22} kg·m·s^{-1}. *(Note: This is a relativistic electron traveling at 95% of the speed of light, so you can't use p = mv here.)*

This decay also produces a gamma ray with a photon energy of 5.0707×10^{-14} J.

(a) Calculate the wavelength of the electron. *[2 marks]*

$$\lambda = \frac{h}{p} = \frac{6.626070\times10^{-34}\ \frac{J}{Hz}}{8.376\times10^{-22}\ \frac{kg\cdot m}{s}} \times \frac{1\ \frac{kg\cdot m^2}{s^2}}{1\ J} \times \frac{1\ Hz}{1\ \frac{1}{s}} = 7.911\times10^{-13}\ m$$ 4 sig. fig.

(b) Calculate the wavelength of the gamma radiation. *[3 marks]*

Step 1: Calculate frequency of light (gamma radiation)

$E = h\nu$

$$\nu = \frac{E}{h} = \frac{5.0707\times10^{-14}\ J}{6.626070\times10^{-34}\ \frac{J}{Hz}} = 7.6527\times10^{19}\ Hz$$ 5 sig. fig.

Step 2: Calculate wavelength of light (gamma radiation)

$c = \lambda\nu$

$$\lambda = \frac{c}{\nu} = \frac{2.997925\times10^{8}\ \frac{m}{s}}{7.6527\times10^{19}\ Hz} = 3.9175\times10^{-12}\ m$$ 5 sig. fig.

Steps can be combined using the formula $E = \frac{hc}{\lambda}$

(c) Calculate the momentum of the gamma-ray photon. *[2 marks]*

$\lambda = \frac{h}{p}$

$$p = \frac{h}{\lambda} = \frac{6.626070\times10^{-34}\ \frac{J}{Hz}}{3.9175\times10^{-12}\ m} \times \frac{1\ \frac{kg\cdot m^2}{s^2}}{1\ J} \times \frac{1\ Hz}{1\ \frac{1}{s}} = 1.6914\times10^{-22}\ \frac{kg\cdot m}{s}$$ 5 sig. fig.

NAME:_____ Student Number:_____

8. Calculate the wavelength of the photon emitted when the electron in a Be^{3+} ion makes a transition from $n = 4$ to $n = 2$. **[8 marks]**

Report your answer in nm.

Step 1: Recognize that $Z = 4$ for Be and all cations of Be

Step 2: Calculate the energies of both orbitals ($n = 2$ and $n = 4$)

$$E_{n=2} = -R_H \frac{Z^2}{n^2} = -R_H \frac{(4)^2}{(2)^2} = -4R_H$$

$$E_{n=4} = -R_H \frac{Z^2}{n^2} = -R_H \frac{(4)^2}{(4)^2} = -R_H$$

Step 3: Calculate the energy difference between the two orbitals (and therefore the energy of the photon)

$$\Delta E = E_{n=2} - E_{n=4} = (-4R_H) - (-R_H) = -3R_H$$

$$\Delta E = -3(2.179872 \times 10^{-18}\ J) = -6.539616 \times 10^{-18}\ J$$

$$E_{photon} = |\Delta E| = |-6.539616 \times 10^{-18}\ J| = 6.539616 \times 10^{-18}\ J$$ 7 sig. fig.

Step 4: Calculate the wavelength of the photon (either stepwise or using $E = \frac{hc}{\lambda}$)

$$\nu = \frac{E}{h} = \frac{6.539616 \times 10^{-18}\ J}{6.626070 \times 10^{-34}\ \frac{J}{Hz}} = 9.869524 \times 10^{15}\ Hz$$ 7 sig. fig.

$$\lambda = \frac{c}{\nu} = \frac{2.997925 \times 10^{8}\ \frac{m}{s}}{9.869524 \times 10^{15}\ Hz} = 3.037558 \times 10^{-8}\ m$$ 7 sig. fig.

Step 5: Convert wavelength into nanometers

$$\lambda = 3.037558 \times 10^{-8}\ m \times \frac{10^{9}\ nm}{1\ m} = 30.37558\ nm$$ 7 sig. fig.

n and Z are exact numbers, so they have an infinite number of sig. fig. and therefore do not affect the sig. fig. of the calculated wavelength.*

**It is not possible to have a value for n or Z that is not a whole number. That makes them exact numbers. Other examples of exact numbers include 100% when converting something to a percentage and the coefficients in a balanced chemical equation.*

NAME:_____ Student Number:_____

9. ^{123}I is often used in Canadian hospitals for kidney and thyroid imaging. It decays to ^{123}Te. **[14 marks]**

(a) Write a balanced nuclear reaction for this decay. *[1 mark]*
If there is more than one possible answer, only one answer is required.

$^{123}_{53}I \rightarrow {}^{123}_{52}Te + {}^{0}_{1}\beta$ *or* $^{123}_{53}I + {}^{0}_{-1}e \rightarrow {}^{123}_{52}Te$

(b) Identify the type of decay described by your answer to part (a). *[1 mark]*

positron emission *or* electron capture

(c) Explain (in a few words) why ^{123}I decays as you indicated. *[2 marks]*

^{123}I contains 53 protons ($Z = 53$) and 70 neutrons ($N = 70$).
This places it below the band of stability, suggesting that it must gain neutrons and/or lose protons to reach a stable isotope. Both positron emission and electron capture convert a proton to a neutron, raising the number of neutrons and lowering the number of protons.

(d) The half-life of ^{123}I is 13.1 h. Because of the short half-life, once produced, ^{123}I must be quickly shipped and used. Data sheets provided to hospitals suggest that the product expires after 30 hours. It is sold in capsules that initially have a radioactivity of 3.7 MBq. What is the radioactivity of a capsule at the time of expiry? *[3 marks]*

$N_2 = N_1 \left(\frac{1}{2}\right)^{\Delta t / t_{1/2}}$ therefore $A_2 = A_1 \left(\frac{1}{2}\right)^{\Delta t / t_{1/2}}$

$A_2 = A_1 \left(\frac{1}{2}\right)^{\Delta t / t_{1/2}} = (3.7\ MBq) \left(\frac{1}{2}\right)^{(30\ h)/(13.1\ h)} = 0.76\ MBq$

...continued on next page…

NAME:_____ Student Number:_____

9. …*continued*

(e) The amount of radioactivity of a fresh capsule of ^{123}I might sound like a lot, but it only corresponds to about 0.014 pg of ^{123}I. How much energy is released by the decay of this amount of ^{123}I? *[7 marks]*

Recall reaction equation from part (a) of this question:

$^{123}_{53}I \rightarrow {}^{123}_{52}Te + {}^{0}_{1}\beta$ *or* $^{123}_{53}I + {}^{0}_{-1}e \rightarrow {}^{123}_{52}Te$

Step 1: Calculate mass defect (difference in mass between products and reactants)

$\Delta m = m_{products} - m_{reactants}$ *remember not to include electrons or positrons*

$$\Delta m = \left(122.9042698\ \frac{g}{mol}\right) - \left(122.9055885\ \frac{g}{mol}\right)$$

$$\Delta m = -0.0013187\ \frac{g}{mol}$$ 7 decimal places

Step 2: Calculate energy released by decay of 1 mole of ^{123}I

$$\Delta E = \Delta m c^2 = \left(-0.0013187\ \frac{g}{mol}\right)\left(\frac{1\ kg}{1000\ g}\right)\left(2.997925 \times 10^8\ \frac{m}{s}\right)^2\left(\frac{1\ J}{1\ \frac{kg \cdot m^2}{s^2}}\right)$$

$$\Delta E = -1.1852 \times 10^{11}\ \frac{J}{mol}$$ 5 sig. fig.

Step 3: Calculate moles of ^{123}I which decay

$$n_{I-123} = 0.014\ pg \times \frac{1\ g}{10^{12}\ pg} \times \frac{1\ mol}{122.9055885\ g} = 1.1 \times 10^{-16}\ mol$$ 2 sig. fig.

Step 4: Calculate energy released by decay of this amount of ^{123}I

$$\Delta E = \left(-1.1852 \times 10^{11}\ \frac{J}{mol}\right)(1.1 \times 10^{-16}\ mol) = -1.4 \times 10^{-5}\ J$$ 2 sig. fig.

Step 5: Answer question

Decay of 0.014 pg of ^{123}I releases $1.4 \times 10^{-5}\ J$ of energy.

NAME:_____ Student Number:_____

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

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

$$r_n = a_0 \frac{n^2}{Z} \qquad E_n = -R_H \frac{Z^2}{n^2} \qquad E_k = \frac{1}{2}mv^2 \qquad \Delta E = \Delta m c^2$$

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

Chem 1000 Standard Periodic Table

1												13	14	15	16	17	18
1.0079 **H** 1	2																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	3	4	5	6	7	8	9	10	11	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**	(265) **Rf** 104	(268) **Db** 105	(271) **Sg** 106	(270) **Bh** 107	(277) **Hs** 108	(276) **Mt** 109	(281) **Ds** 110	(280) **Rg** 111	(285) **Cn** 112	(284) **Nh** 113	(289) **Fl** 114	(288) **Mc** 115	(293) **Lv** 116	(294) **Ts** 117	(294) **Og** 118

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	(262) **Lr** 103

Developed by Prof. R. T. Boeré (updated 2016)

NAME:_____ Student Number:_____

Some Useful Masses

${}^{4}_{2}\alpha$	4.001 506 179 u
${}^{1}_{1}p$	1.007 276 467 u
${}^{1}_{0}n$	1.008 664 916 u
${}^{0}_{+1}\beta$	0.000 548 579 9 u
${}^{0}_{-1}\beta$	0.000 548 579 9 u
${}^{123}I$	122.905 588 5 u
${}^{123}Te$	122.904 269 8 u

Band of Stability Graph

The graph below 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

