NAME:______________________________ Student Number:________________________

Fall 2012 **Chemistry 1000 Practice Midterm #2B** ____/ 60 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 exam until after 8:30pm Mountain Time on Monday, November 19th, 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 0/60 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	/ 8
Q2	/ 8
Q3	/ 3
Q4	/ 2
Q5	/ 4
Q6	/ 4
Q7	/ 4
Q8	/ 6
Q9	/ 6
Q10	/ 10
Q11	/ 5

Total	/ 60

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1. Complete the following table, giving the name and symbol for an element meeting each description. *All valid answers are listed.* **[8 marks]**

Description	Symbol	Name
The alkali metal in the 4th period	K	potassium
The noble gas in the 2nd period	Ne	neon
An element in Group 17 that is a gas under standard laboratory conditions	Cl F	chlorine fluorine
The only element in Group 13 which is not a metal	B	boron
The element in the 4th period whose most common ion is a dianion (-2 charge)	Se	selenium
A transition metal that, when neutral, has six valence electrons	Cr Mo W	chromium molybdenum tungsten
The element in the 1st period with the larger atomic radius	H	hydrogen
The element in Group 2 with the smallest atomic radius	Be	beryllium

2. Write balanced chemical equations for each of the following reactions. **[8 marks]**
Include states of matter.

(a) Magnesium metal reacts with liquid bromine.

$$Mg(s) + Br_2(l) \rightarrow MgBr_2(s)$$

(b) Potassium metal reacts with water.

$$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$$

or $$2K(s) + 2H_2O(l) \rightarrow 2K^+(aq) + 2OH^-(aq) + H_2(g)$$

(c) Lithium metal reacts with nitrogen.

$$6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$$

(d) Aluminium oxide reacts with aqueous acid.

$$Al_2O_3(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2O(l)$$

or $$Al_2O_3(s) + 6H_3O^+(aq) \rightarrow 2Al^{3+}(aq) + 9H_2O(l)$$

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3. **[3 marks]**

(a) What is a diagonal relationship?

A diagonal relationship is a similarity in reactivity between an element in the second period and the element in the third period that is in the next main group. It is observed between Li and Mg, between Be and Al, and between B and Si.

(b) Give an example of a reaction that can be rationalized by a diagonal relationship and explain briefly.

$$6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$$

Li is similar to Mg in that it is the only alkali metal which reacts with $N_2(g)$.

or

$$BeO(s) + 2OH^-(aq) + H_2O(l) \rightarrow [Be(OH)_4]^{2-}(aq)$$

Be is similar to Al in that they both have amphoteric oxides (i.e. BeO and Al_2O_3 both react with base as well as with acid – which is unusual; most metal oxides only react with acid).

4. **[2 marks]**

(a) What is passivation?

Some metals are coated with a thin layer of metal oxide which acts as a protective layer, reducing the reactivity of the metal with oxygen, water, etc. This can occur naturally (due to high reactivity of the 'naked' metal) but can also be enhanced (as in anodized aluminium).

(b) Give an example of a passivated metal.

aluminium (Al)

5. In the first step of the industrial process for refining aluminium, the ore is treated with base. Explain what this step accomplishes and give a balanced chemical equation for the reaction. **[4 marks]**

Aluminium ore contains oxides and hydroxides of aluminium which are contaminated by oxides of other metals (e.g. iron(III) oxide).

Aluminium oxides (and hydroxides) are amphoteric. They can react with aqueous acid or aqueous base. Most other metal oxides are basic and will only react with aqueous acid.

When aluminium ore is treated with base, therefore, the aluminium oxides/hydroxides react with it to give a soluble product (the $[Al(OH)_4]^-$ anion) while the other metal oxides remain in the solid state and can be filtered out. This allows separation of aluminium species from all other metal species.

$$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2[Al(OH)_4]^-(aq)$$

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6. Consider the following set of elements: **[4 marks]**

Na, Mg, Al, and F

Which of these elements has the highest second ionization energy? Why?
Your explanation must include the definition of a second ionization energy.

The second ionization energy of an element is the energy required to remove a second electron from an atom – in other words, to remove an electron from A^+ to give A^{2+}.

It is therefore most useful to look at the electron configurations for the cation formed from each element and compare how difficult it will be to remove an electron from each:

Na^+	$1s^2\ 2s^2\ 2p^6$	Al^+	$1s^2\ 2s^2\ 2p^6\ 3s^2$
Mg^+	$1s^2\ 2s^2\ 2p^6\ 3s^1$	F^+	$1s^2\ 2s^2\ 2p^4$

The electron to be removed from Mg^+ or Al^+ is in a 3*s* orbital whereas the electron to be removed from Na^+ or F^+ is in a 2*p* orbital. Compared to electrons in the n = 2 shell, electrons in the n = 3 shell are:

a) farther away from the nucleus, and

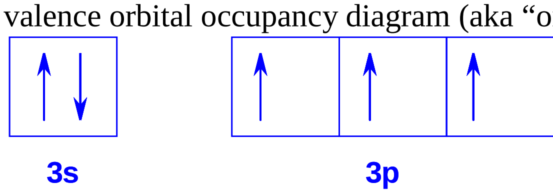
b) better shielded from the nuclear charge by core electrons.

So, it requires less energy to remove an electron from Mg^+ or Al^+ than from Na^+ or F^+.

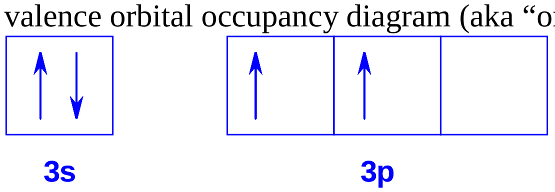
Na^+ has 11 protons in its nucleus while F^+ has only 9 protons in its nucleus. Even though Na^+ has two more electrons than F^+, neither electron can fully shield the charge from a proton, so the 2*p* electrons in Na^+ will feel a greater effective nuclear charge than those in F^+. Therefore, it requires more energy to remove an electron from Na^+ than from F^+.

7. The general trend for electron affinity is for the values to increase as you go from left to right across a period. **[4 marks]**

(a) Draw a valence orbital occupancy diagram (aka "orbital box diagram") for phosphorus. *[1 mark]*



(b) Draw a valence orbital occupancy diagram (aka "orbital box diagram") for silicon. *[1 mark]*



(c) Explain why the electron affinity for phosphorus is smaller than that for silicon. *[2 marks]*

Electron affinity is the energy released when adding another electron to a neutral atom.

The next electron added to Si goes into the unoccupied 3*p* orbital.

The next electron added to P goes into one of the three occupied 3*p* orbitals. Thus, it is repelled by the other electron in its orbital. This raises the energy of the anion and, as such, less energy is released when the anion is formed.

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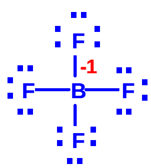
8. It is possible to make octet-rule-obeying species with the general formula AF_4^z where z is the charge (possibly zero) and A = boron, carbon or nitrogen. **[6 marks]**

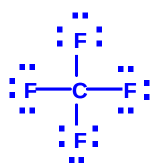
For each species:

- draw a Lewis diagram (including any non-zero formal charges), and
- clearly indicate what the overall charge must be

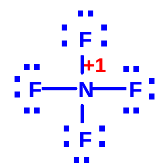
(a) BF_4^z (b) CF_4^z (c) NF_4^z



overall charge = –1



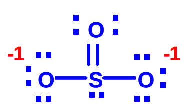
no overall charge

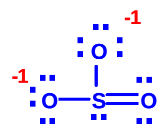


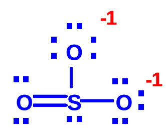
overall charge = +1

9. **[6 marks]**

(a) Draw all formal-charge-minimized resonance structures for the sulfite ion (SO_3^{2-}). *Include non-zero formal charges on the appropriate atoms.* *[4 marks]*



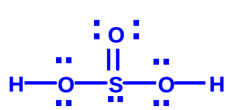




(b) What is the average S-O bond order for the sulfite ion? *[1 mark]*

1⅓

(c) Draw a valid Lewis diagram for sulfurous acid (H_2SO_3). *[1 mark]*



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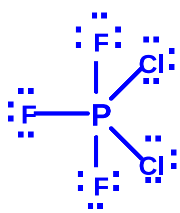
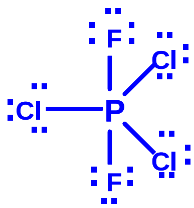
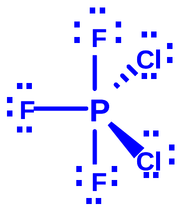
10. Experimental evidence shows that PF_3Cl_2 has a dipole moment whereas PCl_3F_2 does not. Answer the following questions regarding these two molecules and this experimental observation. **[10 marks]**

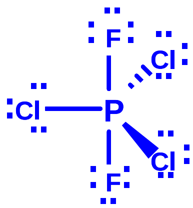
(a) Draw a Lewis diagram for each of these compounds. *[2 marks]*





(b) Draw each of these two compounds showing the correct VSEPR geometry, and give the name for the molecular geometry of each compound. *[4 marks]*





both molecules are trigonal bipyramidal

(c) Explain why the F and Cl atoms occupy the positions shown in your VSEPR structures. *[2 marks]*

Cl atoms are larger than F atoms. In a trigonal bipyramidal molecule, the larger atoms (or lone pairs) are located at the equatorial sites.

(d) Explain why PF_3Cl_2 has a dipole moment whereas PCl_3F_2 does not. *[2 marks]*

In PCl_3F_2, the three $P\text{-}Cl_{(equatorial)}$ dipoles cancel and the two $P\text{-}F_{(axial)}$ dipoles cancel. Thus, the molecule has no net dipole.

In PF_3Cl_2, the two $P\text{-}F_{(axial)}$ dipoles cancel, but the three $P\text{-}X_{(equatorial)}$ dipoles do not cancel (since a P-F bond has a different dipole moment than a P-Cl bond). As such, PF_3Cl_2 has a net dipole.

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11. **[5 marks]**

(a) Write a balanced chemical equation for the electrolysis of molten sodium chloride. *Include states of matter.* *[1 mark]*

$$2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$$

(b) If we want to make 0.600 kg of sodium metal, what mass of sodium chloride must be electrolyzed? Report your answer in kg. *[4 marks]*

Step 1: Write balanced chemical equation (done in part (a)) for reaction

Step 2: Calculate number of moles of Na(l) to be produced

$$n_{Na} = \frac{m_{Na}}{M_{Na}} = 0.600 kgNa \times \frac{1 molNa}{22.9898 gNa} = 0.0261 kmolNa$$

Because the final answer it to be reported in kilograms, I have left the moles in kilomoles. If you're not comfortable with that, it's fine to convert it to 26.1 mol Na.

Step 3: Use mole ratio to calculate number of moles of NaCl(l) to be consumed

$$n_{NaCl} = n_{Na} \times \frac{2 molNaCl}{2 molNa} = 0.0261 kmolNa \times \frac{2 molNaCl}{2 molNa} = 0.0261 kmolNaCl$$

Step 4: Calculate mass of NaCl(l) to be consumed

$$m_{NaCl} = n_{NaCl} \times M_{NaCl} = 0.0261 kmolNaCl \times \frac{58.4425 gNaCl}{1 molNaCl} = 1.53 kgNaCl$$

If you used 26.1 mol Na = 26.1 mol NaCl, your mass will be in grams (1.53×10^3 g NaCl) which must then be converted into kilograms.

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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)	$2.179\ 872$ x 10^{-18} J
Electron mass	$5.485\ 799 \times 10^{-4}$ u	Speed of light in vacuum	$2.997\ 925$ x 10^{8} m·s^{-1}
Ideal gas constant (R)	8.314 462 J·mol^{-1}·K^{-1} 8.314 462 m^3·Pa·mol^{-1}·K^{-1}	Standard atmospheric pressure	1 bar = 100 kPa

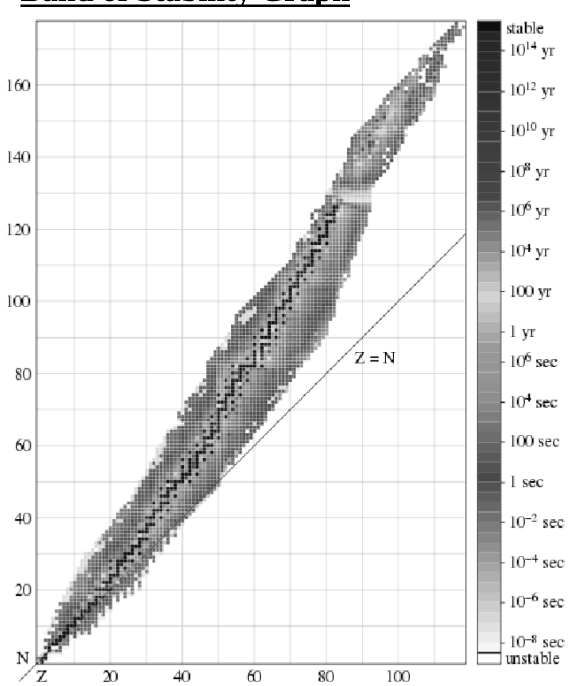
Formulae

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

$r_n = a_0 \dfrac{n^2}{Z}$ $\qquad E_n = -R_H \dfrac{Z^2}{n^2}$ $\qquad E_k = \dfrac{1}{2}mv^2$ $\qquad PV = nRT$

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

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																	2
6.941 **Li** 3	4											10.811 **B** 5	12.011 **C** 6	14.0067 **N** 7	15.9994 **O** 8	18.9984 **F** 9	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	18
19	20	44.9559 **Sc** 21	47.88 **Ti** 22	23	24	25	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	33	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