NAME:______________________________ Student Number:________________________

Fall 2017 **Chemistry 1000 Midterm #2A** ____/ 75 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 8:00pm Mountain Time on Tuesday, November 7th, 2017 (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 0/75 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 2017
The University of Lethbridge

Spelling matters!

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

Flourine = 

Question Breakdown

Q1	/ 16
Q2	/ 6
Q3	/ 6
Q4	/ 3
Q5	/ 8
Q6	/ 4
Q7	/ 7
Q8	/ 7
Q9	/ 10
Q10	/ 8

Total	/ 75

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1. Fill in each blank with the word or phrase that best completes the sentence. **[16 marks]**

If your answer is an element, you must provide the <u>name and symbol for that element</u> for full credit. *For ionic compounds, only the formula is necessary (unless it is a "The name for… is" question).*

(a) An example of a metal that reacts with water at room temperature is _sodium (Na)_. *There are many other acceptable answers to this question including K, Rb, Cs, Ca, Sr and Ba.*

(b) An example of a metal that does **<u>not</u>** react with water at room temperature is _aluminium (Al)_. *There are many other acceptable answers to this question including Be, Cr, Fe, Co, Ni, Pd, Pt, Cu, Ag, Au, and Zn.*

(c) The element whose cations give a violet flame test is _potassium (K)_.

(d) The alkali metal with the largest ionization energy is _lithium (Li)_.

(e) Alkaline earth metals tend to make ions with a charge of _+2_.

(f) The passivation layer on the surface of aluminium metal is made of _Al_2O_3_.

(g) An example of an ionic compound that gives off carbon dioxide gas when heated is _$CaCO_3$_. *or any other carbonate salt*

(h) Two common packing arrangements for atoms in a metal lattice are _cubic closest packing_ and _hexagonal closest packing_. *(Alternative phrasing: "Two common types of metal lattice are ___ and ___.")* *body-centered cubic is also an acceptable answer, and face-centered cubic is an acceptable alternative name for cubic closest packing*

(i) As a general rule, lattice energy increases when _charge of ions_ increases.

(j) As a general rule, lattice energy decreases when _size of ions_ increases.

(k) The energy released when a neutral atom in the gas phase gains an electron is that element's _electron affinity_.

(l) The name for NaF is _sodium fluoride_.

(m) The name for FeS is _iron(II) sulfide_.

(n) The name for $CoCl_3$ is _cobalt(III) chloride_.

(o) Dissolving CO_2 in water makes the water more _acidic_.

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2. Complete the following table. You may find the partial periodic table (copied from the Data Sheet) helpful. *Misspelled elements will not get full credit.* **[6 marks]**

Atomic Number (*Z*)	**Symbol**	**Name**
2	He	helium
4	Be	beryllium
11	Na	sodium
14	Si	silicon
19	K	potassium
20	Ca	calcium

CHEM 1000 Partial Periodic Table

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1																	2
3	4											5	12.011 **C** 6	14.0067 **N** 7	15.9994 **O** 8	18.9984 **F** 9	20.1797 **Ne** 10
11	12											26.9815 **Al** 13	14	30.9738 **P** 15	32.066 **S** 16	35.4527 **Cl** 17	39.948 **Ar** 18
19	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	33	78.96 **Se** 34	79.904 **Br** 35	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	(260) **Lr** 103	

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3. **[6 marks]**

(a) Write the electron configuration for each of the ions below. Use the noble gas abbreviation. *Do NOT abbreviate so much that the valence electrons are not explicitly listed! [3 marks]*

i. Se^{2-} $[Ar]\ 4s^2 3d^{10} 4p^6$

ii. Br^- $[Ar]\ 4s^2 3d^{10} 4p^6$

iii. Cl^- $[Ne]\ 3s^2 3p^6$

(b) Rank the ions from smallest to largest (by radius). *[1 mark]*

smallest _______Cl^-_______ _______Br^-_______ _______Se^{2-}_______ largest

(c) Justify your ranking. *[2 marks]*

Cl^- is smaller than Br^- and Se^{2-} because Cl^- only has three shells of electrons whereas Br^- and Se^{2-} both have four shells of electrons.

Br^- and Se^{2-} both have 36 electrons, but Br^- has 35 protons whereas Se^{2-} has only 34 protons. The nucleus of Se^{2-} therefore has a smaller positive charge, so its electrons are less strongly attracted to the nucleus. This makes Se^{2-} larger than Br^-.

4. For each of the following statements, circle whether it is TRUE or FALSE. **[3 marks]**

IF a statement is FALSE, briefly explain why ***or*** provide an example that proves the statement to be false. *This is required to get credit for choosing "FALSE".*

(a) Na^+ is highly reactive and does not occur in nature. TRUE / [✓ FALSE]

$NaCl$ is a very common salt containing Na^+.

Neutral Na is highly reactive and does not occur in nature.

(b) All salts of group 2 metals are soluble in water. TRUE / [✓ FALSE]

Carbonates and sulfates are examples of group 2 metal salts that are insoluble in water.

(c) The reactivity of group 2 metals increases with increasing mass. [✓ TRUE] / FALSE

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5. Write balanced chemical equations for each of the following reactions. **[8 marks]**
Include states of matter. If no reaction occurs, write "NO REACTION".

(a) Lithium metal is heated with nitrogen gas.

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

(b) Potassium metal is added to water.

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

(c) Barium carbonate ($BaCO_3$) is added to a solution of aqueous acid.

$BaCO_3(s)\ +\ 2\,H^+(aq)\ \rightarrow\ Ba^{2+}(aq)\ +\ H_2O(l)\ +\ CO_2(g)$

(d) Aqueous sodium chloride is subjected to electrolysis in the chlor-alkali process.

$2\,NaCl(aq)\ +\ 2\,H_2O(l)\ \rightarrow\ 2\,NaOH(aq)\ +\ H_2(g)\ +\ Cl_2(g)$

6. Beryllium and aluminium are related by the diagonal relationship, indicating that their chemistry shows some similarities. **[4 marks]**

(a) Both beryllium metal and aluminium metal react with aqueous base. Write a balanced chemical equation for one of these reactions. *[2 marks]*

$2\,Al(s)\ +\ 2\,OH^-(aq)\ +\ 6\,H_2O(l)\ \rightarrow\ 2\,[Al(OH)_4]^-(aq)\ +\ 3\,H_2(g)$

or $Be(s)\ +\ 2\,OH^-(aq)\ +\ 2\,H_2O(l)\ \rightarrow\ [Be(OH)_4]^{2-}(aq)\ +\ H_2(g)$

(b) Give another example of the diagonal relationship between beryllium and aluminium. *[1 mark]*

Beryllium oxide (BeO) and aluminium oxide (Al_2O_3) are both amphoteric.

or Beryllium oxide (BeO) and aluminium oxide (Al_2O_3) both react with aqueous base.

or Beryllium oxide (BeO) and aluminium oxide (Al_2O_3) are both insoluble in water.

The metals are not amphoteric. Their oxides are amphoteric.

(c) Give the names of another pair of elements that have a similar diagonal relationship. *[1 mark]*

lithium and magnesium

7. Aluminium metal is prepared by electrolysis of molten Al_2O_3. **[7 marks]**

(a) Why is it necessary for the Al_2O_3 to be melted before it can be electrolyzed? *[1 mark]*

Solid Al_2O_3 won't conduct an electrical current. Liquid Al_2O_3 can. Without an electrical current, electrolysis is impossible.

(b) Aluminium ore (bauxite) is not pure. Give an example of one contaminant that must be removed before the Al_2O_3 can be electrolyzed. *[1 mark]*

Fe_2O_3

(c) How is the bauxite purified before it is electrolyzed? *[5 marks]*

- Write balanced chemical equations for each reaction in the purification process. Your last equation should have Al_2O_3 as a product. *Include states of matter.*
- Identify any points at which a separation is necessary (e.g. a filtration or similar) and clearly identify which component contains the aluminium.

Step 1: Add aqueous base to dissolve Al^{3+} salts

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

or $$Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$$

or $$Al(O)(OH)(s) + OH^-(aq) + H_2O(l) \rightarrow [Al(OH)_4]^-(aq)$$

Most metal oxides do not react with aqueous base, so remain solid.

Separate the solid and aqueous phases, and keep the aqueous phase (containing the Al^{3+} salts).

Step 2: Add just enough acid to neutralize the solution

$$[Al(OH)_4]^-(aq) + H^+(aq) \rightarrow Al(OH)_3(s) + H_2O(l)$$

Thus, Al^{3+} is precipitated out as $Al(OH)_3$.

Separate the solid and aqueous phases, and keep the solid phase (containing the Al^{3+} salts).

Step 3: Heat to dehydrate the $Al(OH)_3$

$$2\,Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3\,H_2O(g)$$

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8. Once pure Al_2O_3 has been obtained, it is electrolyzed. **[7 marks]**

(a) Complete the following chemical equation for the electrolysis of Al_2O_3 by balancing it and adding states of matter. *[2 marks]*

$$\_2\_\ Al_2O_3(l) + \_3\_\ C(s) \rightarrow \_4\_\ Al(l) + \_3\_\ CO_2(g)$$

half-reactions: $Al^{3+}(l) + 3\,e^- \rightarrow Al(l)$

$2\,O^{2-}(l) + C(s) \rightarrow CO_2(g) + 4\,e^-$

(b) What mass of carbon must be consumed in order to produce 2.50 tons of aluminium metal (1 ton = 1000 kg)? *[5 marks]*

Report your answer in kg.

Step 1: Calculate moles of Al to be produced

$$m_{Al} = 2.50\ ton \times \frac{1000\ kg}{1\ ton} \times \frac{1000\ g}{1\ kg} = 2.50 \times 10^6\ g$$ 3 sig. fig.

$$n_{Al} = 2.50 \times 10^6\ g \times \frac{1\ mol}{26.9815\ g} = 9.27 \times 10^4\ mol$$ 3 sig. fig.

Step 2: Use mole ratio to calculate moles of C to be consumed

$$n_C = 9.27 \times 10^4\ mol\ Al \times \frac{3\ mol\ C}{4\ mol\ Al} = 6.95 \times 10^4\ mol\ C$$ 3 sig. fig.

Step 3: Calculate mass of C to be consumed

$$m_C = 6.95 \times 10^4\ mol \times \frac{12.011\ g}{1\ mol} = 8.35 \times 10^5\ g$$ 3 sig. fig.

$$m_C = 8.35 \times 10^5\ g \times \frac{1\ kg}{1000\ g} = 835\ kg$$ 3 sig. fig.

It would be fine to recognize that 1 ton = 1 Mg and work in Mg and Mmol.

It would also be fine to convert the mass of Al into kg then work in kg and kmol.

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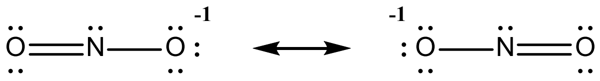
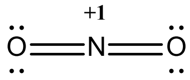
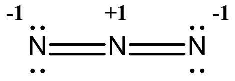
9. **[10 marks]**

(a) Complete the table below. If more than one valid resonance structure can be drawn for the ion, **draw all valid resonance structures**. *[6 marks]*
Include any non-zero formal charges on the appropriate atom(s).

Chemical Formula	**Lewis Diagram(s)**
NO_2^-	
NO_2^+	 *Some students also included the two resonance structures with one single bond and one triple bond. If one was included, both must have been included, and formal charges must have been correct (-1 on the single bonded O, +1 on the triple bonded O and +1 on the central N).* *These resonance structures are <u>inferior</u> to the one shown because there is more formal charge *and* adjacent atoms have formal charge of the same sign (which should be avoided).*
N_3^-	 *Some students also included the two resonance structures with one single bond and one triple bond. If one was included, both must have been included, and formal charges must have been correct (-2 on the single bonded N and +1 on the central N).* *These resonance structures are <u>inferior</u> to the one shown because they do not spread out the formal charge as much.*

(b) Based on your Lewis diagram(s), *[2 marks]*

i. What is the average $N-O$ bond order in NO_2^-?

1.5

ii. What is the average $N-O$ bond order in NO_2^+?

2

(c) Based on your Lewis diagram(s), *[2 marks]*

i. What is the bond angle for NO_2^-? *Use ~ to indicate an angle that is not exact.*

~120°

ii. What is the bond angle for NO_2^+? *Use ~ to indicate an angle that is not exact.*

180°

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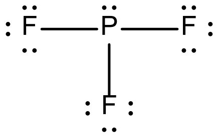
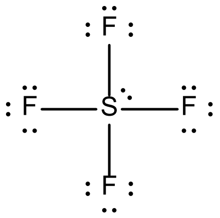
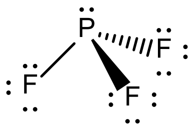
10. **[8 marks]**

(a) Complete the table below. Draw **one** valid Lewis diagram for each molecule. *[6 marks]*
Include any non-zero formal charges on the appropriate atom(s).

Chemical Formula	**Lewis Diagram**	**Electron Group Geometry (in words)**	**Molecular Geometry (in words)**
PF_3		tetrahedral	trigonal pyramidal
SF_4		trigonal bipyramidal	seesaw

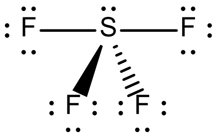
(b) Re-draw each of the molecules to show the correct geometry according to VSEPR.
You do not need to label bond angles. *[2 marks]*

i. PF_3



Wedge and dashed line must be next to each other. If there is a line between them, the shape is not trigonal pyramidal. Also, the shape must look pyramidal. Adding a wedge and dashed line to a trigonal planar picture does not show trigonal pyramidal.

ii. SF_4



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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}	Standard atmospheric pressure	1 bar = 100 kPa
	8.314 462 m^{3}·Pa·mol^{-1}·K^{-1}		

Formulae

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

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

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

CHEM 1000 Partial Periodic Table

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1																	2
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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
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