Name: ________________________ Student Number: _____________________

Chemistry 1000 Practice Final Exam B
Based on Fall 2012 Test (Content Updated to Fall 2017 Curriculum)

INSTRUCTIONS

1) Read the exam carefully before beginning. There are 21 questions on pages 2 to 14 followed by 2 pages of "Data Sheet" (including periodic table) and a blank page for any rough work. **Please ensure that you have a complete exam. If not, let an invigilator know immediately**. All pages must be submitted at the end of the exam.
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) You may use a calculator.
5) Show your work for all calculations. Answers without supporting calculations will not be given full credit.
6) Marks will be deducted for improper use of significant figures and for numerical answers with incorrect/missing units.
7) **Do not open the exam until you are told to begin. Beginning prematurely will result in removal of your exam paper and a mark of 0.**
8) You have **3 hours** to complete this exam. Nobody may leave the exam room during the first hour or the last 15 minutes of the exam.

Q	Mark
1	/ 4
2	/ 6
3	/ 12
4	/ 4
5	/ 4
6	/ 5
7	/ 10
8	/ 2
9	/ 5
10	/ 3

Q	Mark
11	/ 9
12	/ 12
13	/ 10
14	/ 7
15	/ 18
16	/ 2
17	/ 3
18	/ 5
19	/ 3
20	/ 7
21	/ 1

Total	**/ 132**

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1. Complete the table below. **[4 marks]**

Name	Formula
copper(II) hydroxide	
phosphate ion	
magnesium-24 ion	
	HNO_3

2. Write balanced chemical equations for each of the following processes: **[6 marks]**

(a) ^{133}Ba decays by electron capture

(b) Nitrogen reacts with magnesium

(c) Potassium reacts with water

(d) Calcium reacts with bromine

(e) Aqueous sodium chloride is subjected to electrolysis

(f) Aluminium oxide is reacted with aqueous sodium hydroxide.

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3. Chlorine, bromine and iodine are all capable of forming several different oxoanions. On the other hand, fluorine can only form one oxoanion, and it is not stable. **[12 marks]**

(a) Draw the Lewis diagram for the one oxoanion containing fluorine. *[1 mark]*
Include any nonzero formal charges on the appropriate atoms.

(b) Complete the table below for any two of the four oxoanions of iodine. *[10 marks]*

Formula	Lewis Diagram*	Name of Molecular Geometry	Oxidation State of I	Name

** Include any nonzero formal charges on the appropriate atoms.*

(c) Briefly explain why fluorine behaves differently from the other halogens (in this context). *[1 mark]*

4. Lithium-6 and lithium-7 are the only two stable isotopes of lithium. **[4 marks]**

(a) Predict the likely modes of decay for isotopes of lithium that are heavier than the stable isotopes. Briefly explain your reasoning. *[2 marks]*

(b) Predict the likely modes of decay for isotopes of lithium that are lighter than the stable isotopes. Briefly explain your reasoning. *[2 marks]*

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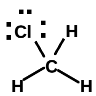
5. For each pair of species, list the intermolecular force(s) which can act between the two species. Also, circle the strongest intermolecular force acting between those two species. **[4 marks]**

(a) I^- and chloromethane (see diagram below)



chloromethane

(b) H_2O and NH_3

6. Which of the gases PF_3 or BF_3 would you expect to have the higher value of *a* in the van der Waals equation and why? **[5 marks]**

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7. Define each term and give an example of each (a compound or a specific balanced reaction, as appropriate). **[10 marks]**

(a) Lewis acid

(b) Brønsted base

(c) Hydrogen bonding

(d) Ionization energy

(e) Electron affinity

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8. Choose an element from group 14, group 15 or group 16 that has more than one allotrope. Give two different allotropes that this element can form. You can use either molecular formulae or names. **[2 marks]**

9. **[5 marks]**

(a) Draw the Lewis diagrams for carbon monoxide and carbon dioxide.
Include any nonzero formal charges on the appropriate atoms. *[2 marks]*

(b) What is unusual about the Lewis diagram for carbon monoxide? *[1 mark]*

(c) Is carbon dioxide a Lewis acid or a Lewis base? *[1 mark]*

(d) Is carbon monoxide a Lewis acid or a Lewis base? *[1 mark]*

10. Borane (BH_3) does not exist in nature. Rather, it exists as diborane. **[3 marks]**

(a) Draw the Lewis diagram for diborane. *[1 mark]*

(b) What is unusual about this structure? *[1 mark]*

(c) Why do you think that diborane exists while borane does not? *[1 mark]*

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11. **[9 marks]**

(a) Draw a full set of 3*d* orbitals. *[5 marks]*
Each orbital must be drawn on a properly labeled set of axes

(b) In an octahedral complex, these orbitals split into two sets of different energies. Indicate which orbitals belong to the higher-energy set and which to the lower-energy set. Explain your choices. *[4 marks]*

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12. **[12 marks]**

(a) Draw an orbital energy diagram for the valence shell (both occupied and unoccupied orbitals) of a beryllium atom. *[2 marks]*

(b) Give one possible complete set of quantum numbers for an electron in the highest energy occupied orbital of beryllium. *[2 marks]*

(c) Explain why we can't measure an electron affinity for beryllium. *[3 marks]*

(d) What is an emission spectrum? *[1 mark]*

(e) The lowest energy transition in the emission spectrum of a beryllium atom has a wavelength of 455 nm. To what transition does this line correspond? *[1 mark]*

(f) Calculate the energy difference between the two energy levels involved in the transition described in part (e). *[3 marks]*

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13. Natural nitrogen samples from different sources have different molar masses. Two particular samples of nitrogen have molar masses of 14.00648 g/mol and 14.00711 g/mol respectively. **[10 marks]**

(a) Based on the molar masses given above, what is likely to be the most common isotope of nitrogen? *[1 mark]*

(b) How many protons and how many neutrons would the nucleus contain for the isotope you named in part (a)? *[2 marks]*

(c) What experimental method could we use to determine the molar mass? Explain briefly what data we get from this experiment and how a molar mass is calculated from that data. *[4 marks]*

(d) For the two samples described above and the experiment you described in part (c), what data would be the same (within experimental error) and what data would be different? Can you say (at least qualitatively) how they would differ? In other words, what data would be larger/smaller for what sample? *[3 marks]*

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14. In proton therapy, a beam of protons is used to destroy tumors inaccessible to normal surgical procedures. Ions (alpha particles, protons, etc.) progressively slow down as they pass through biological tissues, and they do most of their damage just as they are about to stop. By choosing their energy correctly, it is therefore possible to target a tumor at a very specific depth, causing much less damage to intervening tissues. In one particular operation, protons with a kinetic energy of 3.0×10^{-11} J per proton were used. **[7 marks]**

(a) Calculate the wavelength of these protons. *[3 marks]*

(b) At the stage at which tumors are noticed and treated, they typically have dimensions on the order of centimeters. How does the wavelength of the protons compare? What, if anything, would this imply for their use in proton therapy? *[2 marks]*

(c) A radiotherapist plans to deliver a proton therapy dose of 3.5 Gy to a tumor with an estimated mass of 32 g.

(i) How much energy would this dose represent? *[1 mark]*

(ii) How many protons would be needed to deliver this dose? *[1 mark]*

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15. In power plants, the burning of coal produces SO_2 because the coal contains a small amount of sulfur (hence sulfur is also burned). One way to remove SO_2 from the flue gases of power plants is to react it with an aqueous solution of H_2S. One product of this reaction is sulfur and the other is water.
[18 marks]

(a) How many moles of SO_2 will be produced by burning 1.00 ton (1.00×10^3 kg) of coal containing 3.00% sulfur by mass? *[3 marks]*

(b) Write a balanced chemical equation for the reaction between SO_2 and H_2S. *[1 mark]*

(c) What are the oxidation states of sulfur in SO_2 and H_2S? *[2 marks]*

S in SO_2: ________ S in H_2S: ________

(d) At 25 ˚C and 100 kPa, how many liters of hydrogen sulfide (H_2S) gas would be needed to remove all the SO_2 formed in (a)? *[3 marks]*

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15. *continued…*

(e) If the untreated flue gases of power plants are released into the environment, SO_2 will react with another pollutant, NO_2, to produce sulfur trioxide and nitrogen monoxide. Draw a formal charge-minimized Lewis diagram for SO_3. *[2 marks]*

(f) Fill in the following table for SO_3. *[4 marks]*

Name of Molecular Geometry	Bond Angles	Average S-O Bond Order	Molecular Polarity? (circle one)
			polar / nonpolar

(g) When SO_3 dissolves in atmospheric water, we get acid rain! Write a balanced chemical equation for the reaction of SO_3 with water. *[1 mark]*

(h) In the Lewis acid-base reaction described in part (g), is SO_3 acting as a Lewis acid or a Lewis base? Support your answer with a reaction equation showing the movement of electrons using curly arrows. *[2 marks]*

16. **[2 marks]**

(a) On what quantum number(s) does the orbital energy in a hydrogen atom depend? *[1 mark]*

(b) Would your answer be the same for helium? If not, state the quantum number(s) on which the energy of an orbital in a helium atom depends. *[1 mark]*

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17. The Haber-Bosch process is arguably one of the most important industrial reactions. **[3 marks]**

(a) Write a balanced chemical equation for the reaction involved in the Haber-Bosch process. Include all states of matter. *[2 marks]*

(b) What property of nitrogen makes this reaction so challenging? *[1 mark]*

18. Consider the following complex: $[Co(OH)_6]^{4-}$ **[5 marks]**

(a) What is the co-ordination number of cobalt in this complex? *[1 mark]*

(b) What is the oxidation state of cobalt in this complex? *[1 mark]*

(c) How many d electrons does cobalt have in this complex? *[1 mark]*

(d) Would you expect this complex to absorb light with a longer or shorter wavelength than $[Co(NH_3)_6]^{2+}$? Explain. *[2 marks]*

19. **[3 marks]**

(a) Draw both isomers of $[Fe(H_2O)_3(OH)_3]$. *[2 marks]*
Your pictures must clearly show the correct geometry at Fe.

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(b) Clearly label your answers to part (a) as the *fac* isomer and the *mer* isomer. *[1 mark]*

20. The ground-state electron configuration of tantalum (Ta) is [Xe] $6s^2\ 4f^{14}\ 5d^3$. **[7 marks]**

(a) The most common oxidation states of tantalum are III, IV and V (i.e. +3, +4 and +5). Write the ground-state electron configuration for each of the following ions: *[3 marks]*

Ta^{3+}

Ta^{4+}

Ta^{5+}

(b) Which of these ions would you expect to yield coloured complexes? Explain briefly. *[4 marks]*

BONUS: In a special chelating solvent called diglyme, the following reaction can be performed

$$TaCl_{5(sol)} + 6Na_{(s)} + 6CO_{(g)} + 12diglyme_{(l)} \rightarrow \left[Ta(CO)_6\right]^-_{(sol)} + 5Cl^-_{(sol)} + 6\left[Na(diglyme)_2\right]^+_{(sol)}$$

Here, the subscript (sol) indicates a species dissolved in diglyme (the <u>sol</u>vent).

What is the oxidation state of the tantalum atom in the product complex? *[1 mark]*

What would the corresponding ground-state electron configuration be? *[1 mark]*

21. What was the most useful and/or interesting thing you learned in CHEM 1000? **[1 mark]**

…AND THAT'S ALL FOR CHEM 1000.
HAPPY HOLIDAYS!

DATA SHEET

Fundamental Constants and Conversion Factors

Atomic mass unit (u)	$1.660\ 539 \times 10^{-27}$ kg	Kelvin temperature scale	0 K = -273.15 ºC
Avogadro's number (N_A)	$6.022\ 141 \times 10^{23}$ mol^{-1}	Planck's constant	$6.626\ 070 \times 10^{-34}$ J·Hz^{-1}
Bohr radius (a_0)	$5.291\ 772 \times 10^{-11}$ m	Proton mass	1.007 277 u
Electron charge (*e*)	$1.602\ 177 \times 10^{-19}$ C	Neutron mass	1.008 665 u
Electron mass	$5.485\ 799 \times 10^{-4}$ u	Rydberg Constant (R_H)	$2.179\ 872 \times 10^{-18}$ J
Ideal gas constant (R)	8.314 462 J·mol^{-1}·K^{-1}	Speed of light in vacuum	$2.997\ 925 \times 10^{8}$ m·s^{-1}
	8.314 462 m^3·Pa·mol^{-1}·K^{-1}	Standard atmospheric pressure	1 bar = 100 kPa
		Volume	1000 L = 1 m^3

Formulae

$c = \lambda \upsilon$ $\quad E = h\upsilon$ $\quad p = mv$ $\quad \lambda = \frac{h}{p}$ $\quad \Delta x \cdot \Delta p > \frac{h}{4\pi}$ $\quad r_n = a_0 \frac{n^2}{Z}$ $\quad E_n = -R_H \frac{Z^2}{n^2}$

$\overline{E_k} = \frac{1}{2} m\overline{v^2} = \frac{3}{2}\frac{RT}{N_A}$ $\quad v_{rms} = \sqrt{\overline{v^2}} = \sqrt{\frac{3RT}{M}}$ $\quad PV = nRT$ $\quad \left(P + a\frac{n^2}{V^2}\right)(V - bn) = nRT$

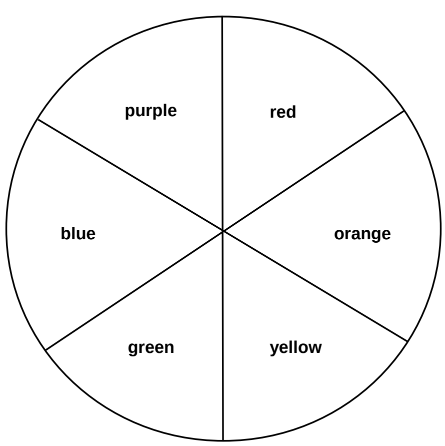
$\Delta E = \Delta mc^2$ $\quad A = -\frac{\Delta N}{\Delta t}$ $\quad A = kN$ $\quad \ln\left(\frac{N_2}{N_1}\right) = -k(t_2 - t_1)$ $\quad \ln(2) = k \cdot t_{1/2}$

$pK_a \approx 8 - 5p$ for oxoacids $O_pE(OH)_q$

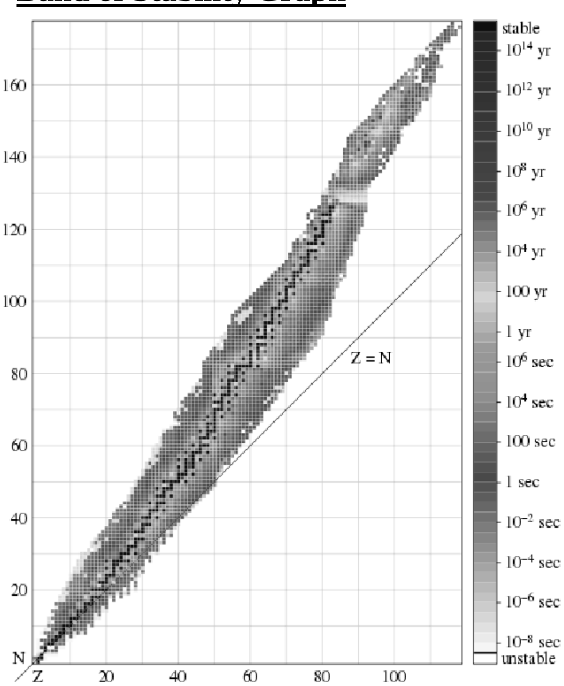
Spectrochemical Series

strong field weak field

CN^- > ethylenediamine > NH_3 > $EDTA^{4-}$ > H_2O > oxalato > OH^- > F^- > Cl^- > Br^- > I^-



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.

DATA SHEET

Chemistry 1000 Standard 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