Name: _____ Student Number: _____

Chemistry 1000 Final Exam (Version A)
April 22nd, 2013

INSTRUCTIONS

1) Read the exam carefully before beginning. There are 20 questions on pages 2 to 12 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	/ 12
2	/ 6
3	/ 6
4	/ 3
5	/ 5
6	/ 5
7	/ 5
8	/ 6
9	/ 4
10	/ 4

Q	Mark
11	/ 4
12	/ 6
13	/ 9
14	/ 8
15	/ 2
16	/ 4
17	/ 4
18	/ 8
19	/ 8
20	/ 1

Total	/ 110

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1. Give an example of each of the following: **[12 marks]**

(a) An alkali metal. *(name and symbol)*

(b) A transition metal. *(name and symbol)*

(c) An element in Group 13 that is not a metal. *(name and symbol)*

(d) An element that reacts spontaneously with nitrogen gas. *(name and symbol)*

(e) A nonmetal that reacts spontaneously with chlorine gas. *(name and symbol)*

(f) An element whose neutral atoms are diamagnetic. *(name and symbol)*

(g) An element with 5 valence electrons when it is neutral. *(name and symbol)*

(h) An element which can form a dianion (anion with -2 charge). *(name and symbol)*

(i) An acid that does not contain any hydrogen atoms.

(j) A molecule that can hydrogen bond with other molecules of the same compound.

(k) A molecule with trigonal pyramidal geometry.

(l) A nonpolar molecule that contains one or more polar bonds.

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2. Complete the table below. Only complete the last column for isotopes which you have identified as radioactive. **[6 marks]**

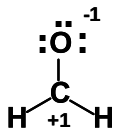
Isotope	**N**	**Z**	**Radioactive?** *(circle yes or no)*	**Predicted mode(s) of decay** *(for radioactive isotopes only)*
	3	5	yes / no	
	50	30	yes / no	
^{225}Rn			yes / no	

3. Complete the table below. **[6 marks]**

Name	**Formula**
calcium nitrate	
	$TiCl_3$
cobalt(II) sulfide	
	Na_2SO_3
perchloric acid	
	H_2SO_3

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4. While marking organic chemistry lab reports this semester, I saw many students draw Lewis structures similar to the one below:



This is not a good Lewis structure for the CH_2O molecule. **[3 marks]**

(a) Draw a good Lewis structure for CH_2O. *[1 mark]*

(b) Give <u>two</u> reasons why your structure is better than the one drawn above. *[2 marks]*

5. Consider the following complex ions: **[5 marks]**

$[Cu(OH_2)_6]^{+}$ $[Fe(OH_2)_6]^{2+}$ $[Cr(OH_2)_6]^{3+}$ $[Ti(OH_2)_6]^{4+}$

(a) Which of the complex ions would you expect to be the strongest acid? *[1 mark]*

(b) Which of the complex ions would you expect to give coloured solutions? *[2 marks]*
Marks will be deducted for listing incorrect ions in addition to correct ones.

(c) Choose one of the complex ions.

(i) Complex ion chosen:

(ii) Identify the Lewis acid from which this complex ion is made. *[1 mark]*

(iii) Identify the Lewis base from which this complex ion is made. *[1 mark]*

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6. **[5 marks]**

(a) Using the noble gas abbreviation, write the electron configuration for iron. *[1 mark]*

(b) Using the noble gas abbreviation, write the electron configuration for cobalt. *[1 mark]*

(c) Which of these two elements would you expect to have a higher ionization energy? Explain your answer. Your explanation must make it clear that you understand what the term "ionization energy" means and must be based on chemical principles. *[3 marks]*

7. **[5 marks]**

(a) Using the noble gas abbreviation, write the electron configuration for Fe^{2+}. *[1 mark]*

(b) Using the noble gas abbreviation, write the electron configuration for Co^{3+}. *[1 mark]*

(c) Which of these two ions would you expect to have a larger radius? Explain your answer. *[3 marks]*

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8. Write balanced chemical equations for the following reactions. **[6 marks]**
Include states of matter.

(a) Calcium reacts with oxygen.

(b) $SO_{3(g)}$ reacts with water.

(c) Potassium reacts with bromine.

(d) Aqueous sodium chloride is electrolyzed.

(e) Molten (liquid) sodium chloride is electrolyzed.

(f) Ozone decays to oxygen.

9. Write balanced chemical equations for the following reactions. **[4 marks]**

(a) ^{18}F decays by positron emission.

(b) ^{208}Po decays by alpha emission.

(c) ^{68}Ge decays by electron capture.

(d) Fusion of two ^{3}He atoms. In addition to the main product, two protons are ejected.

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10. If a kettle is used repeatedly to boil hard water, a white solid builds up inside. **[4 marks]**

(a) What is hard water? *[1 mark]*

(b) What is the white solid that has built up on the inside of the kettle? *[1 mark]*

(c) The white solid can be removed using any acidic cleaner (vinegar, CLR, etc.). Use one or more balanced chemical equations to demonstrate what happens when an acidic cleaner is added to the white solid. *You may use $H^+_{(aq)}$ as a generic acid or you may use any acid of your choice in your answer. Include states of matter.* *[2 marks]*

11. You are given a mixture of $Al_2O_{3(s)}$ and $CuO_{(s)}$. Explain how you could separate these two compounds and recover both as solids. **[4 marks]**
Your answer must include balanced chemical equations with states of matter.

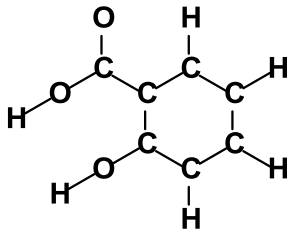
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12. Draw a valid Lewis structure for each of the molecules or ions below. **[6 marks]**

(a) BCl_3 (b) H_2O_2

(c) NO_2^+ (d) NO_2^-

13. Salicylic acid ($C_7H_6O_3$) is produced by willow trees. It is used to make aspirin. The skeleton for salicylic acid is shown below: **[9 marks]**



(a) Add electrons to the skeleton above to turn it into a valid Lewis structure. *[2 marks]*

(b) Including the one you drew above, how many valid resonance structures could you draw for this molecule? *[1 mark]*

(c) Which bond(s) do you expect to be the shortest in this molecule? *[1 mark]*

(d) Which bond(s) do you expect to be the longest in this molecule? *[1 mark]*

(e) On your structure above, circle/highlight one of the carbon atoms and one of the oxygen atoms (one that is attached to an H). *[4 marks]*

(i) What is the electron group geometry of the circled/highlighted carbon atom?

(ii) What is the molecular geometry of the circled/highlighted carbon atom?

(iii) What is the electron group geometry of the circled/highlighted oxygen atom?

(iv) What is the molecular geometry of the circled/highlighted oxygen atom?

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14. Consider each of the following sets of quantum numbers. **[8 marks]**

- If it is a valid set of quantum numbers, name and draw one orbital that it could describe. *Your drawing must include labeled axes and show phases.*
- If it is not a valid set of quantum numbers, explain why not.

(a) $n = 3 , \ell = 2 , m_\ell = 1$

(b) $n = 2 , \ell = 2 , m_\ell = -2$

(c) $n = 5 , \ell = 1 , m_\ell = -1$

(d) $n = 4 , \ell = -1 , m_\ell = 1$

15. Only three quantum numbers are listed in the question above. What is the symbol for the fourth quantum number, and what does it describe? **[2 marks]**

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16. The emission spectrum for hydrogen atoms contains four wavelengths of visible light. Why was it an important observation that hydrogen atoms can only emit a limited number of wavelengths of light? How did this observation change our understanding of the structure of the atom? **[4 marks]**

17. Argon fluoride (ArF) lasers are commonly used for LASIK eye surgery. They produce light with a wavelength of 193 nm. **[4 marks]**

(a) To what type of light does this wavelength correspond? Circle the correct answer.*[1 mark]*

visible ultraviolet infrared

(b) Calculate the energy of light produced by an ArF laser. *[3 marks]*
Report your answer in J/mol.

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18. The half-life of ^{206}Bi is 6.24 days. The half-life of ^{207}Bi is 38 years. **[8 marks]**

(a) This information does not tell you which (if either) of the two isotopes would be more dangerous to be exposed to. What additional information would you need to assess the relative risks of exposure to each isotope? *Give at least two suggestions.* *[2 marks]*

(b) What *can* you conclude about the two isotopes based on the information presented in this question? *[1 mark]*

(c) How long would it take for 1 kg ^{206}Bi to decay until only 1 mg of the original isotope was left? *[4 marks]*

(d) There is only one stable isotope of Bi. What is it? *[1 mark]*

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19. A 4.0 L bottle of bleach contains 4.5% NaOCl (4.5 g NaOCl per 100 mL bleach). The bleach is prepared from sodium hydroxide and chlorine gas:

$$__NaOH_{(aq)} + __ Cl_{2(g)} \rightarrow __ NaOCl_{(aq)} + __ NaCl_{(aq)} + __ H_2O_{(l)}$$

[8 marks]

(a) Balance the reaction equation above. *[1 mark]*
Answer directly on the equation by filling in the blanks.

(b) Calculate the concentration of NaOCl in the bottle of bleach. *[3 marks]*
Report your answer in mol/L.

(c) Calculate the minimum mass of NaOH required to make 4.0 L of bleach. *[4 marks]*

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

…AND THAT'S ALL FOR CHEM 1000.
HAVE A GREAT SUMMER!

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	$6.022\,141 \times 10^{23}$ 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

Formulae

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

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

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

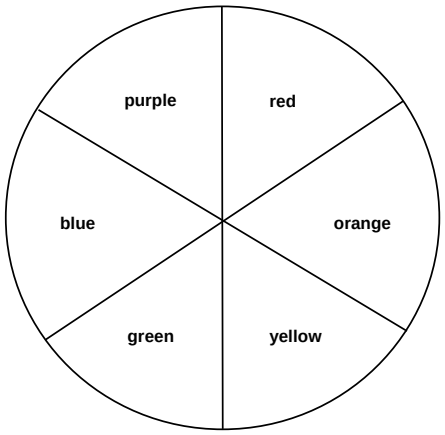
$pK_a \approx 15.14 - 88.16\,pm\left(\frac{z^2}{r}\right)$ **or** $pK_a \approx 15.14 - 88.16\,pm\left[\frac{z^2}{r} + 0.0960\,pm^{-1}\left(\chi_{Pauling} - 1.50\right)\right]$ for aqua complexes

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

Spectrochemical Series

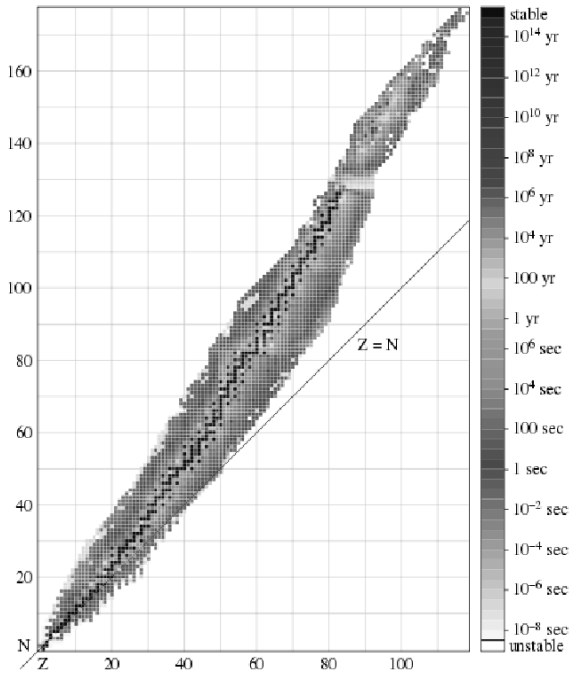
strong field weak field

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



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.

Band of Stability Graph



DATA SHEET

Chemistry 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**	(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