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)*

Li (lithium), Na (sodium), K (potassium), Rb (rubidium), Cs (cesium), Fr (francium)

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

Any element in Groups 3-12
Common choices included Fe (iron), Cu (copper), Ni (nickel), Ti (titanium)

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

B (boron)

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

Li (lithium), Mg (magnesium), Ca (calcium), Sr (strontium), Ba (barium), Ra (radium)

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

P (phosphorus), S (sulfur), Se (selenium)

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

Any element in Groups 2, 12 or 18 (or a lanthanide or actinide with no unpaired electrons)
Common choices included He (helium), Ne (neon), Mg (magnesium), Ca (calcium)

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

Any element in Groups 5 or 15 (or an actinide or lanthanide with 5 valence electrons)
Common choices included N (nitrogen), P (phosphorus), As (arsenic), V (vanadium)

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

O (oxygen), S (sulfur), Se (selenium), Te (tellurium)

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

Any Lewis acid with no hydrogen atoms (any answer that is an anion is incorrect)
Common choices included CO_2, SO_3, BF_3, BCl_3, $AlCl_3$

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

Any molecule containing a hydrogen atom bonded to N, O or F.
Common choices included H_2O, NH_3, HF

(k) A molecule with trigonal pyramidal geometry.

The central atom must have three atoms attached and one lone pair
Most common choice was NH_3

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

Molecule must be symmetric so that bond dipoles cancel
Common choices included CO_2, SO_3, CCl_4

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

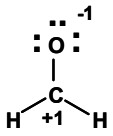
Isotope	**N**	**Z**	**Radioactive?** *(circle yes or no)*	**Predicted mode(s) of decay** *(for radioactive isotopes only)*
^{8}B	3	5	yes	positron emission *or* electron capture
^{80}Zn	50	30	yes	beta decay
^{225}Rn	139	86	yes	alpha decay

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

Name	**Formula**
calcium nitrate	$Ca(NO_3)_2$
titanium(III) chloride	$TiCl_3$
cobalt(II) sulfide	CoS
sodium sulfite	Na_2SO_3
perchloric acid	$HClO_4$
sulfurous acid	H_2SO_3

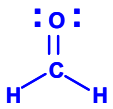
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4. While marking organic chemistry lab reports this semester, I saw many students draw Lewis structures similar to the one below:



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]*

1. all atoms obey the octet rule (in the initial structure, the carbon atom does not)
2. formal charges have been minimized

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]*

$[Ti(OH_2)_6]^{4+}$

It has the largest positive charge on the metal cation

(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.

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

These contain metal cations with partially filled d subshells.

Cu^+ is [Ar] $3d^{10}$. Fe^{2+} is [Ar] $3d^6$. Cr^{3+} is [Ar] $3d^3$. Ti^{4+} is [Ne] $3s^2$ $3p^6$.

(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]*

The metal cation: Cu^+, Fe^{2+}, Cr^{3+} or Ti^{4+} (depending on the complex ion chosen)

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

water (H_2O)

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6. **[5 marks]**

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

[Ar] $4s^2$ $3d^6$

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

[Ar] $4s^2$ $3d^7$

(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]*

cobalt (Co)

Ionization energy is the energy required to remove one electron from a neutral atom in the gas phase.

Co has one more proton and one more electron than Fe.

Since the extra electron in Co does not fully shield the positive charge of the extra proton, the effective nuclear charge felt by the valence electrons of Co is greater.

Since the valence electrons in Co feel a stronger pull to the nucleus, it requires more energy to remove one of them.

7. **[5 marks]**

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

[Ar] $3d^6$

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

[Ar] $3d^6$

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

Fe^{2+}

The two ions have the same number of electrons (with the same electron configuration) but Co^{3+} has one more proton than Fe^{2+}.

Because Fe^{2+} has fewer protons in its nucleus, the effective nuclear charge felt by its valence electrons is smaller (compared to Co^{3+}).

Since the valence electrons in Fe^{2+} are less strongly attracted to the nucleus, they are not pulled in as tightly so the ionic radius is larger.

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8. Write balanced chemical equations for the following reactions. **[6 marks]**
Include states of matter.
Remember that, for anything to have an aqueous state of matter, water must be present!

(a) Calcium reacts with oxygen.

$$2\,Ca_{(s)} + O_{2(g)} \rightarrow 2\,CaO_{(s)}$$

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

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$$

or $SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(l)}$ *if water is limiting reagent*

(c) Potassium reacts with bromine.

$$2\,K_{(s)} + Br_{2(l)} \rightarrow 2\,KBr_{(s)}$$

(d) Aqueous sodium chloride is electrolyzed.

$$2\,NaCl_{(aq)} + 2\,H_2O_{(l)} \rightarrow 2\,NaOH_{(aq)} + H_{2(g)} + Cl_{2(g)}$$

or $2\,Cl^-_{(aq)} + 2\,H_2O_{(l)} \rightarrow 2\,OH^-_{(aq)} + H_{2(g)} + Cl_{2(g)}$

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

$$2\,NaCl_{(l)} \rightarrow 2\,Na_{(l)} + Cl_{2(g)}$$

(f) Ozone decays to oxygen.

$$2\,O_{3(g)} \rightarrow 3\,O_{2(g)}$$

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

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

$${}^{18}_{9}F \rightarrow {}^{0}_{+1}\beta + {}^{18}_{8}O$$

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

$${}^{208}_{84}Po \rightarrow {}^{4}_{2}\alpha + {}^{204}_{82}Pb$$

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

$${}^{68}_{32}Ge + {}^{0}_{-1}e \rightarrow {}^{68}_{31}Ga$$

or ${}^{68}_{32}Ge + {}^{0}_{-1}\beta \rightarrow {}^{68}_{31}Ga$

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

$$2\,{}^{3}_{2}He \rightarrow 2\,{}^{1}_{1}p + {}^{4}_{2}He$$

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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]*

Hard water is water containing high concentrations of dissolved Ca^{2+} and Mg^{2+} ions. *(It may also contain high concentrations of other dications and trications e.g. Fe^{3+}.)*

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

$CaCO_3$ (calcium carbonate) and/or $MgCO_3$ (magnesium carbonate)

(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]*

$$CaCO_{3(s)} + 2\,H^+_{(aq)} \rightarrow Ca^{2+}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

or

$$CaCO_{3(s)} + 2\,H^+_{(aq)} \rightarrow Ca^{2+}_{(aq)} + H_2CO_{3(aq)}$$

and $\quad H_2CO_{3(aq)} \Leftrightarrow H_2O_{(l)} + CO_{2(g)}$

Note that these two equations combine to give the overall equation listed as the first answer. Also, you would need to use proper equilibrium arrows (which were not available in the program I used to type up the answer key).

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.

Al_2O_3 is an amphoteric oxide. CuO is a basic oxide (like all metal oxides except BeO and Al_2O_3).

As such, Al_2O_3 will react with base and can therefore be dissolved in aqueous base:

$$Al_2O_{3(s)} + 2\,OH^-_{(aq)} + 3\,H_2O_{(l)} \rightarrow 2\,[Al(OH)_4]^-_{(aq)}$$

CuO will not react with aqueous base, so $CuO_{(s)}$ can be filtered out.

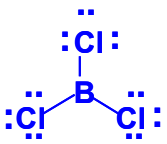
To get the $Al_2O_{3(s)}$ back, add acid to neutralize the anion then heat to dehydrate and evaporate off the resulting water:

$$[Al(OH)_4]^-_{(aq)} + H^+_{(aq)} \rightarrow Al(OH)_{3(s)} \quad \text{then} \quad 2\,Al(OH)_{3(s)} \rightarrow Al_2O_{3(s)} + 3\,H_2O_{(g)}$$

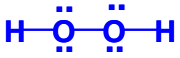
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12. Draw a valid Lewis structure for each of the molecules or ions below. **[6 marks]**

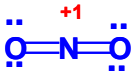
(a) BCl_3



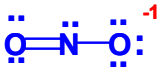
(b) H_2O_2



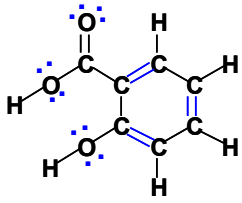
(c) NO_2^+



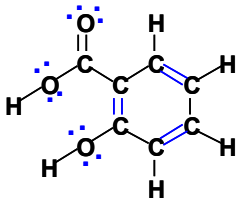
(d) NO_2^-



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]**



or



(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]*

2 *both shown above*

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

O-H *H is a very small atom, so the C-H and O-H bonds should be shortest. O is smaller than C, so expect O-H to be shorter than C-H.*

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

C-C *C and O have similar radii (both in period 2), so we look at bond order. Assuming atoms with similar radii, bond length decreases with increasing bond order so the C-C and C-O single bonds should be longest. C has a larger radius than O, so C-C is expected to be longer than C-O.*

(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?

trigonal planar

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

trigonal planar

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

tetrahedral

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

bent

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

Any 3d orbital:

$3d_{xy}$, $3d_{xz}$, $3d_{yz}$, $3d_{x^2-y^2}$ or $3d_{z^2}$

See notes or textbook for pictures. Remember that phases alternate from lobe to lobe.

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

not allowed

ℓ must be between 0 and n-1

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

Any 5p orbital:

$5p_x$, $5p_y$ or $5p_z$

See notes or textbook for pictures. Remember that the two lobes have opposite phases.

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

not allowed

ℓ cannot be negative! it must be between 0 and n-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]**

m_s describes electron spin

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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]**

- Before these observations, the Rutherford model was used to describe the atom. In this model, electrons existed in a cloud around the nucleus and could have any energy. If this was the case, electrons in any atom should be able to absorb (and later emit) light with any energy. Since energy is inversely proportional to wavelength $\left(E = \frac{hc}{\lambda}\right)$, this can be restated as "electrons in any atom should be able to absorb (and later emit) light with any wavelength".
- The inconsistency between experimental evidence and the Rutherford model of the atom meant that this model could not be correct. It was replaced by the Bohr model of the atom, which introduced the concept of orbitals for electrons.
- In the Bohr model of the atom, the energy of electrons was quantized (i.e. there was a fixed set of allowed values). Each orbital had a specific allowed energy (though more than one orbital could have the same energy – e.g. the three different 2p orbitals have the same energy).
- Thus, an atom could only absorb (and later emit) light whose energy was equal to the difference in energy between two different orbitals. In this way, the Bohr model of the atom was consistent with the new experimental evidence

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.

Step 1: Calculate the energy of a single photon (in J). You must convert wavelength into meters.

$$\lambda = 193 nm \times \frac{1m}{10^9 nm} = 1.93 \times 10^{-7} m$$

$$E_{photon} = \frac{hc}{\lambda} = \frac{\left(6.626070 \times 10^{-34} \frac{J}{Hz}\right)\left(2.997925 \times 10^{8} \frac{m}{s}\right)}{\left(1.93 \times 10^{-7} m\right)} \times \frac{1 Hz}{1 \frac{1}{s}} = 1.03 \times 10^{-18} J$$

Step 2: Calculate the energy of the light in J/mol. There are N_A photons in 1 mole of photons. (N_A = Avogadro's number)

$$E_{molar} = E_{photon} \times N_A = \left(1.03 \times 10^{-18} \frac{J}{photon}\right)\left(6.022141 \times 10^{23} \frac{photons}{mol}\right) = 6.20 \times 10^{5} \frac{J}{mol}$$

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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]*

There were a few different good approaches to this question. The answers below are representative but not exhaustive.

- the absorbed dose from decay of each isotope and the biological effectiveness factor (Q) from decay of each isotope *(allows calculation of the equivalent dose)*
- the absorbed dose from decay of each isotope and the equivalent dose from decay of each isotope
- the energy of the radiation released as each isotope decays and the type of radiation released as each isotope decays
- the quantity of each isotope (e.g. the mass of each) and the equivalent dose from decay of each isotope

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

^{206}Bi has a much faster rate of decay than ^{207}Bi.

(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]*

Step 1: In order to compare the two masses, they must both be in the same units.

$$m_1 = 1kg \times \frac{1000g}{1kg} = 1000g \qquad m_2 = 1mg \times \frac{1g}{1000mg} = 0.001g$$

Step 2: Use the half-life to calculate the decay constant (k) for ^{206}Bi

$$\ln(2) = k \cdot t_{1/2}$$

$$k = \frac{\ln(2)}{t_{1/2}} = \frac{\ln(2)}{6.24d} = 0.111d^{-1}$$

Step 3: Calculate the time required for this decay. Recognize that, since we are only dealing with one isotope (with one mass), the number of atoms is directly proportional to the mass of the sample $\left(\text{mass of isotope} = \frac{\text{mass of sample}}{\#\text{atoms of isotope in sample}}\right)$.

As such, we can adapt the $\ln\left(\frac{N_2}{N_1}\right) = -k(t_2 - t_1)$ formula to $\ln\left(\frac{m_2}{m_1}\right) = -k(t_2 - t_1)$ where $t_2 - t_1$ is the time required for the decay.

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$$\ln\left(\frac{N_2}{N_1}\right) = -k(t_2 - t_1)$$

$$\ln\left(\frac{m_2}{m_1}\right) = -k(t_2 - t_1)$$

$$t_2 - t_1 = -\frac{\ln\left(\frac{m_2}{m_1}\right)}{k} = -\frac{\ln\left(\frac{1000\,g}{0.001\,g}\right)}{0.111 d^{-1}} = 124 d = 1 \times 10^2 d$$

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

^{209}Bi

As one particularly alert student noticed, this question is technically inaccurate as it was recently shown that all isotopes of Bi are at least slightly radioactive so "none of them" was accepted along with that explanation.

The expected approach to this question was for a student to recognize that if an element has only one stable isotope, the average atomic mass on the periodic table will correspond to the mass of that isotope. So, since the average atomic mass of bismuth is 208.980 u, the stable isotope of Bi will have a mass number of 209.

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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:

$$_2_NaOH_{(aq)} + __Cl_{2(g)} \rightarrow __NaOCl_{(aq)} + __NaCl_{(aq)} + __H_2O_{(l)}$$

[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.

Step 1: Calculate the number of moles of NaOCl in any volume of bleach. I chose 100 mL since I know that 100 mL bleach contains 4.5 g NaOCl. (M_{NaOCl} = 74.4419 g/mol)

$$n_{NaOCl} = 4.5g \times \frac{1mol}{74.4419g} = 0.060mol$$

Step 2: Divide the number of moles of NaOCl by the chosen volume of bleach to give the concentration.

$$c_{NaOCl} = \frac{n}{V} = \frac{0.060mol}{100mL} \times \frac{1000mL}{1L} = 0.60\,\frac{mol}{L}$$

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

Step 1: Calculate the number of moles of NaOCl in 4.0 L of bleach.

$$n_{NaOCl} = 4.0L \times 0.60\,\frac{mol}{L} = 2.4mol$$

Step 2: Use the mole ratio to calculate the number of moles of NaOH required to make this much NaOCl.

$$n_{NaOH} = 2.4\text{ mol NaOCl} \times \frac{2\text{ mol NaOH}}{1\text{ mol NaOCl}} = 4.8\text{ mol NaOH}$$

Step 3: Calculate the mass of NaOH required. (M_{NaOH} = 39.9971 g/mol)

$$n_{NaOCl} = 4.8mol \times \frac{39.9971g}{1mol} = 193g = 1.9 \times 10^2 g$$

If you don't carry all the digits in your calculator through the whole calculation (both steps (b) and (c)), you will introduce rounding error into your final answer.

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

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

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

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

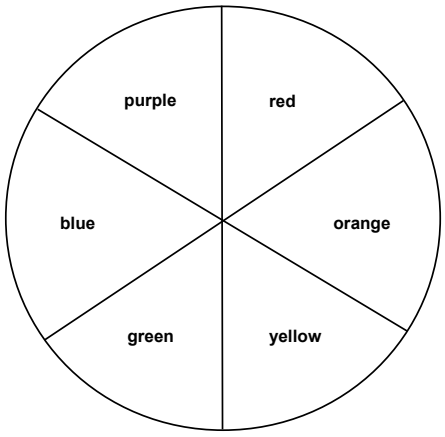
$pK_a \approx 15.14 - 88.16\,pm\left(\frac{z^2}{r}\right)$ **or** $pK_a \approx 15.14 - 88.16\,pm\left[\frac{z^2}{r} + 0.0960\,pm^{-1}\left(\chi_{Pauling} - 1.50\right)\right]$ for aqua complexes

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

Spectrochemical Series

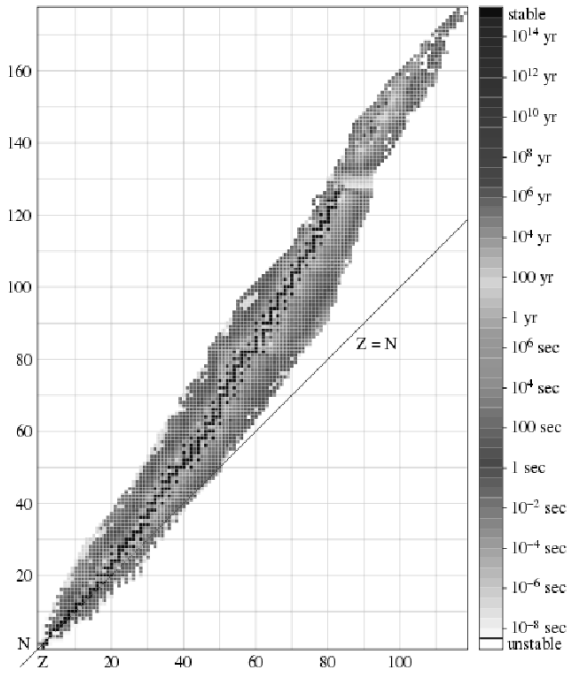
strong field weak field

$CN^- >$ 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