Name: ________________________ Student Number: _____________________

Chemistry 1000 Practice Final Exam A
Based on Fall 2009 Test (Content Updated to Fall 2012 Curriculum)

INSTRUCTIONS

1) Read the exam carefully before beginning. There are 19 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	/ 23
2	/ 3
3	/ 5
4	/ 3
5	/ 3
6	/ 2
7	/ 4
8	/ 3
9	/ 12
10	/ 2

Q	Mark
11	/ 7
12	/ 9
13	/ 8
14	/ 3
15	/ 4
16	/ 10
17	/ 6
18	/ 2
19	/ 1

Total	/ 110

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1. Fill in the blank(s). answers in green are valid alternatives **[23 marks]**

(a) Electronegativity is an atomic property combining ionization energy and electron affinity.

(b) The alkaline earth metal with the smallest atomic radius is _beryllium (Be)_.

(c) The radioactive isotope of hydrogen is _tritium (^3T or ^3H)_.

(d) Phosphorus has three major allotropes. Two of them are _red phosphorus (P)_ and _black phosphorus (P)_. Also white phosphorus (P_4)

(e) One allotrope of carbon that conducts electricity is _graphite (or graphene)_.

(f) Aluminium oxide has the chemical formula _Al_2O_3_. When aluminium oxide is reacted with hydroxide, an anion is formed which has the chemical formula _$[Al(OH)_4]^-$_.

(g) The only intermolecular force active in a nonpolar liquid is _London dispersion force (aka induced dipole-induced dipole attraction)_.

(h) Fluorine has only one isotope. Its mass number is _19_.

(i) Which of the following ions give(s) a colourless solution: $[Ti(OH_2)_6]^{4+}$, $[Mo(OH_2)_6]^{4+}$ or $[Mo(OH_2)_6]^{3+}$? _$[Ti(OH_2)_6]^{4+}$_

(j) The Pauli exclusion principle is a rule stating that _no two electrons in the same atom can have the same set of four quantum numbers_.

(k) The quantum number describing the shape of an orbital is _*l*_.

(l) The photoelectric effect demonstrated the _particle_ nature of light.

(m) An isotope whose N/Z value is too high will most often undergo _beta_ decay.

(n) A neutral atom of ^3He has _2_ proton(s), _2_ electron(s) and _1_ neutron(s).

(o) $Cu(NO_3)_2$ is named _copper(II) nitrate_.

(p) A Gray is a unit used to measure _absorbed dose of radiation_.

(q) The halogen that is a solid at room temperature is _iodine (I)_.

(r) A molecule which has 'see saw' molecular geometry must have _trigonal bipyramidal_ electron group geometry.

(s) B_2H_6 is an unusual molecule because _it contains bonds in which **one** pair of electrons is shared by **three** atoms_.

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2. $CoCO_3$ is used in pottery glazes. Dry $CoCO_3$ consists of light red (pink) crystals. **[3 marks]**

(a) What is the IUPAC name for $CoCO_3$? *[1 mark]*

cobalt(II) carbonate

(b) What colour of light is absorbed by dry $CoCO_3$? *[1 mark]*

green

(c) $CoCO_3$ reacts with acids. Write a balanced chemical equation for the reaction between $CoCO_3$ and $H_3O^+_{(aq)}$. *Include states of matter.* *[1 mark]*

$$\boxed{CoCO_{3(s)} + 2H_3O^+_{(aq)} \rightarrow Co^{2+}_{(aq)} + 3H_2O_{(l)} + CO_{2(g)}}$$

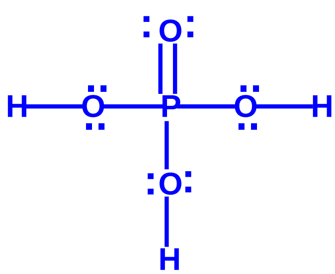
3. H_3PO_4 is a triprotic acid. **[5 marks]**

(a) What is the IUPAC name for H_3PO_4? *[1 mark]*

phosphoric acid

(b) Draw a valid Lewis diagram for H_3PO_4. *[2 marks]*

Include any non-zero formal charges on the appropriate atoms.



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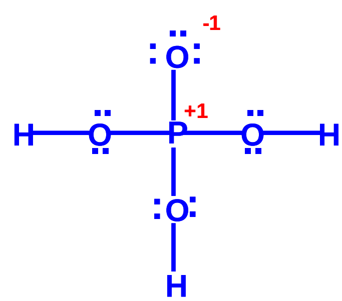

(c) Use your Lewis diagram to calculate an approximate pK_a for H_3PO_4. *[1 mark]*

$$\boxed{pK_a \approx 8 - 5p \approx 8 - 5(1) \approx 3}$$

(d) According to the pK_a you calculated, is H_3PO_4 best classified as a strong acid or a weak acid? *[1 mark]*

weak acid ($pK_a > 0$)

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4. Write a balanced chemical equation for each of the following reactions. **[3 marks]**

(a) Sulfur reacts with chlorine to give disulfur dichloride.

$$\boxed{S_8 + 4Cl_2 \rightarrow 4S_2Cl_2}$$

(b) Lithium is combusted to give lithium oxide.

$$\boxed{4\,Li + O_2 \rightarrow 2\,Li_2O}$$

(c) Fluorine reacts with water to give hydrofluoric acid and oxygen.

$$\boxed{2F_2 + 2H_2O \rightarrow 4HF + O_2}$$

5. Write a balanced chemical equation for each of the following reactions. **[3 marks]**
Include states of matter for all reactants and products.

(a) Barium reacts with oxygen.

$$\boxed{2Ba_{(s)} + O_{2(g)} \rightarrow 2BaO_{(s)}}$$

(b) Zinc reacts with hydrochloric acid.

$$\boxed{Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}}$$

or

$$\boxed{Zn_{(s)} + 2H^+_{(aq)} \rightarrow Zn^{2+}_{(aq)} + H_{2(g)}}$$

or

$$\boxed{Zn_{(s)} + 2H_3O^+_{(aq)} \rightarrow Zn^{2+}_{(aq)} + H_2O_{(l)} + H_{2(g)}}$$

(c) Potassium reacts with chlorine.

$$\boxed{2K_{(s)} + Cl_{2(g)} \rightarrow 2KCl_{(s)}}$$

6. **[2 marks]**

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

Hard water is water containing relatively high concentrations of Ca^{2+} and Mg^{2+} ions.

(b) Briefly describe one method of softening water. *[1 mark]*

In most commercial water softeners, hard water is passed through an ion exchange resin which has been pre-loaded with high concentrations of NaCl. The Ca^{2+} and Mg^{2+} cations bind to the ion exchange resin, releasing the Na^+ cations into the water to replace them.

Alternatively: Hard water can be softened by passing it over a strong base (e.g. $Ca(OH)_2$). This deprotonates the dissolved HCO_3^- ions to give CO_3^{2-} anions which precipitate with the Ca^{2+} and Mg^{2+} cations as $MgCO_3$ and $CaCO_3$.

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7. Lead paint has been prominent in the news lately due to its toxicity. "Lead paint" is not lead metal. "Lead paint" refers to ionic compounds containing lead. **[4 marks]**

(a) What is the electron configuration for a neutral lead atom (Pb)? *[1 mark]*
Use the noble gas abbreviation.

[Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^2$

(b) Lead can form two stable ions. What are their charges? Clearly explain your choices. *[3 marks]*

Pb^{2+} and Pb^{4+} 1 mark

Pb^{4+} has a pseudonoble gas electron configuration: [Xe] $4f^{14}\ 5d^{10}$ This is almost as stable as a noble gas electron configuration and, as a metal, lead will not form anions. 1 mark

Pb^{2+} has a smaller charge than Pb^{4+} and, while its electron configuration is neither noble gas nor pseudonoble gas, it does have all subshells either completely full or completely empty. 1 mark

8. Lead has the following isotopic composition: **[3 marks]**

Isotope	Mass (u)	Abundance (%)
$^{204}_{82}Pb$	203.973	1.4
$^{206}_{82}Pb$	205.974	24.1
$^{207}_{82}Pb$	206.976	22.1
$^{208}_{82}Pb$	207.977	52.4

(a) Calculate the average atomic mass for lead. *[2 marks]*

$$\boxed{\begin{aligned} M_{av} &= \tfrac{1.4\%}{100\%} M_{Pb-204} + \tfrac{24.1\%}{100\%} M_{Pb-206} + \tfrac{22.1\%}{100\%} M_{Pb-207} + \tfrac{52.4\%}{100\%} M_{Pb-208} \\ &= \tfrac{1.4\%}{100\%}(203.973u) + \tfrac{24.1\%}{100\%}(205.974u) + \tfrac{22.1\%}{100\%}(206.976u) + \tfrac{52.4\%}{100\%}(207.977u) \\ &= 2.9u + 49.6u + 45.7u + 109u \\ M_{av} &= 207u \end{aligned}}$$

(b) This average atomic mass can be used for calculations involving neutral lead atoms or for calculations involving lead ions. Why? *[1 mark]*

When we weigh an ionic compound, we are weighing a neutral compound. So, PbO can be considered to consist of Pb^{2+} and O^{2-}. This combination contains the same number of electrons as Pb and O. So, the mass of PbO is the same whether it is calculated from the mass of Pb and the mass of O or calculated from the mass of Pb^{2+} and the mass of O^{2-}.

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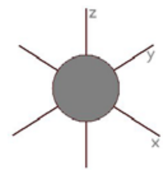
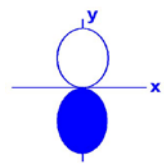
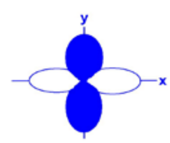
9. Consider each of the following neutral elements:

- an s-block element of the 6th period with 1 valence electron
- a p-block element of the 3rd period with 5 valence electrons
- a d-block element of the 4th period with 4 valence electrons

In the table below, identify each element, sketch a picture of an orbital in which the highest energy electron could be found and provide a valid set of quantum numbers for that highest energy electron. **[12 marks]**

element description	**element** **symbol <u>and</u> name**	**sketch of orbital containing highest energy electron** **(include labeled axes!)**	***n***	***l***	m_l *	m_s **
s-block element in 6th period; 1 valence electron	Cs cesium		6	0	0	+½
p-block element in 3rd period; 5 valence electrons	P phosphorus		3	1	1	+½
d-block element in 4th period; 4 valence electrons	Ti titanium		3	2	2	+½

* m_l values can be anything from $+l$ to $-l$. The value listed is the largest allowed value for m_l. The values do not typically directly correlate to any specific orbital label (i.e. there is no specific value for the p_y orbital shown).

** m_s values can be either +½ or – ½.

10. The ionic radius of K^+ is 133 pm while the ionic radius of Cu^+ is 96 pm. Explain why the radius of Cu^+ is smaller than that of K^+. **[2 marks]**

K^+ has 19 protons and 18 electrons (valence electrons in 3s and 3p).

Cu^+ has 29 protons and 28 electrons (valence electrons in 3d).

While the additional 10 electrons in Cu^+ partially shield the positive charge of the additional 10 protons, that additional positive charge is not fully shielded. As such, the valence electrons in Cu^+ feel a stronger effective nuclear charge and are therefore pulled closer to the nucleus. This makes Cu^+ smaller than K^+.

Both cations have valence electrons in the same shell (n=3) so that is not a significant factor.

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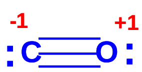
11. The following compounds are a few of the many toxins found in cigarette smoke.**[7 marks]**

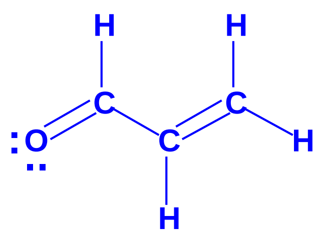
(a) For each of the following compounds, you have been given a skeleton showing all atoms and their connectivity. Turn each skeleton into a valid Lewis diagram by adding the appropriate number of electrons. *[3 marks]*

Include any non-zero formal charges on the appropriate atoms.

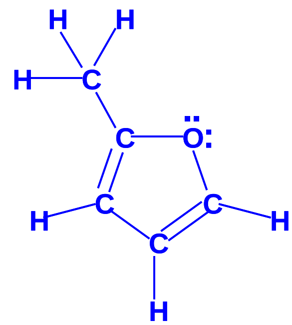
(i)



(ii)



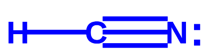
(iii)



(b) For each of the following compounds, you have been given the molecular formula. Draw a valid Lewis diagram for each. *[2 marks]*

Include any non-zero formal charges on the appropriate atoms.

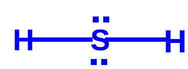
(i) HCN



linear

180°

(ii) H_2S



bent

<109.5°

(c) Underneath each of your Lewis diagrams in part (b), identify the molecular geometry and give the corresponding bond angle. *[2 marks]*

see above

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12. Ozone molecules in the upper atmosphere absorb radiation. If the radiation has a wavelength between 240 nm and 310 nm, the ozone molecules will decompose into oxygen molecules and oxygen atoms. The oxygen atoms then recombine with the oxygen molecules to make more ozone, releasing heat. This converts light energy into heat energy and insulates Earth. **[9 marks]**

$$O_{3(g)} \rightarrow O_{2(g)} + O_{(g)}$$ light energy absorbed

$$O_{2(g)} + O_{(g)} \rightarrow O_{3(g)}$$ heat energy released

(a) What kind of electromagnetic radiation has a wavelength between 240 and 310 nm? *[1 mark]*

Ultraviolet (UV)

(b) Which wavelength represents the minimum amount of energy required for this reaction to proceed: 240 nm or 310 nm? *[1 mark]*

310 nm

(c) Calculate the minimum amount of light energy that must be absorbed to convert 1 mole of ozone into oxygen molecules and atoms. *Report your answer in kJ/mol.* *[4 marks]*

$$\boxed{\lambda = 310 nm \times \frac{1m}{10^9 nm} = 3.10 \times 10^{-7} m}$$

$$\boxed{\begin{aligned} & c = \nu\lambda \\ & \nu = \frac{c}{\lambda} = \frac{2.9979 \times 10^8 \frac{m}{s}}{3.10 \times 10^{-7} m} = 9.67 \times 10^{14} \tfrac{1}{s} = 9.67 \times 10^{14} Hz \end{aligned}}$$

$$\boxed{E_{react-one-molecule} = h\nu = \left(6.626 \times 10^{-34} \tfrac{J}{Hz}\right)\left(9.67 \times 10^{14} Hz\right) = 6.41 \times 10^{-19} J}$$

$$\boxed{E_{molar} = \frac{6.41 \times 10^{-19} J}{1 molecule} \times \frac{6.02214 \times 10^{23} molecules}{1 mole} \times \frac{1kJ}{1000 J} = 386 \tfrac{kJ}{mol}}$$

(d) Draw all valid resonance structures for ozone. *[3 marks]*

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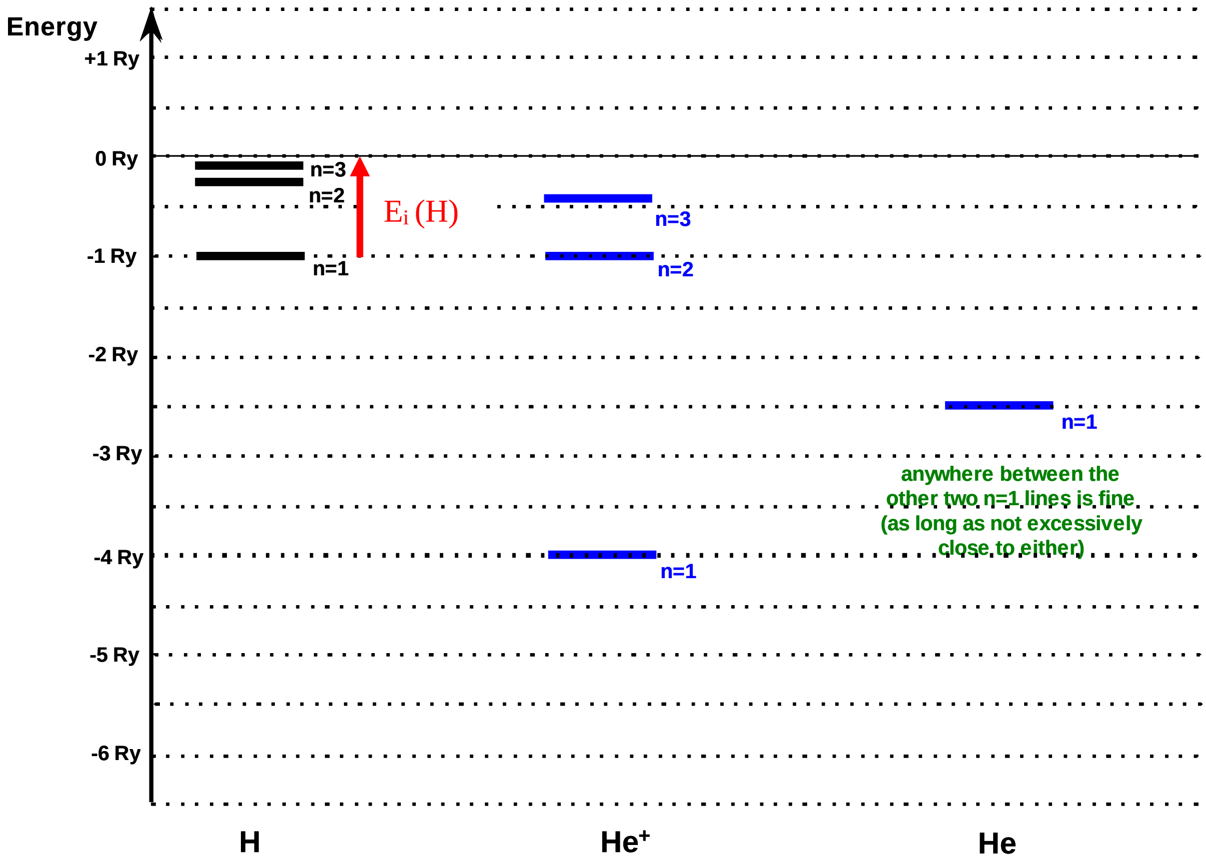
13. The graph below shows the energy levels for three orbitals in a hydrogen atom.
1 Ry = R_H = 2.179 872 x 10^{-18} J **[8 marks]**



(a) On the graph above, clearly show the ionization energy for a hydrogen atom. *[1 mark]*
Leave the He^+ and He columns clear. You will need them for parts (b) and (c).
see red arrow labeled E_i (H)

(b) In the He^+ column, draw and label lines showing the energies of the *n* = 1, *n* = 2 and *n* = 3 orbitals in He^+. *[3 marks]*

(c) It is not possible to calculate the exact energies of the orbitals in He without the help of a computer; however, they can be estimated. In the He column, draw and label a line showing the approximate energy of the *n* = 1 orbital in He. *[2 marks]*

(d) Why is it not possible to calculate the exact energies of the orbitals in He without the help of a computer? *[2 marks]*

He has more than one electron. As such, electron-electron repulsions must be considered as well as nucleus-electron attractions. This makes the mathematics considerably more complex.

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14. For each of the molecules below, identify the dominant intermolecular force. **[3 marks]**

(a) NH_3

hydrogen bonding

(b) CH_4

induced dipole-induced dipole forces (aka London dispersion forces)

(c) CH_2Cl_2

dipole-dipole forces

15. **[4 marks]**

(a) Under what conditions does a gas **NOT** behave ideally? Why? *[2 marks]*

A gas behaves nonideally when it has a high density. Under these conditions, the molecules are close enough together than the volume occupied by the gas particles is significant (making the volume of empty space in the container less than the volume of the container – enough to matter). Also, the molecules are close enough together that they experience intermolecular forces at least some of the time.

(b) Most gases have lower pressures than expected under nonideal conditions. Only a few gases have higher pressures than expected under nonideal conditions. Based on what you know about nonideal gases, suggest one gas that you might expect to have a **higher** pressure than expected, and explain your choice. *[2 marks]*

For a nonideal gas to have a **higher** pressure than expected (based on the ideal gas law), the effect of the "lost volume" occupied by the gas particles must be greater than the effect of the intermolecular forces. Effectively, this means that the intermolecular forces must be *extremely* weak. As such, the gas would have to have a small mass and be nonpolar.

The best suggestions for gases meeting that description would be He or H_2.

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16. Tritium (^3H) has a half-life of 4.50 ×10^3 days. Its decay product is ^3He. **[10 marks]**

(a) Write a balanced equation for the decay of tritium to helium-3. *[1 mark]*

$$\boxed{{}^3_1\mathrm{H} \rightarrow {}^3_2\,\mathrm{He} + {}^0_{-1}\,\beta}$$

(b) What mass of tritium would remain in a 1.00 g sample after 1 year of decay? *[3 marks]*

Step 1: Calculate the decay constant (k) from the half-life

$$\ln(2) = k \cdot t_{1/2} \qquad \text{therefore} \qquad k = \frac{\ln(2)}{t_{1/2}} = \frac{\ln(2)}{4.50\times10^3 d} = 1.54\times10^{-4} d^{-1}$$

Step 2: Calculate the mass of tritium left after 1 year.

One approach to solving this problem would be to calculate the number of atoms (N_1) of tritium in 1.00 g then use the equation below to find N_2 then convert back into a mass.

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

Alternatively, since every atom of tritium has the same mass (3.016 049 278 u), it can abe reasoned that $N_2/N_1 = m_2/m_1$. Therefore, use the equation above to solve for N_2/N_1. That value is equal to m_2/m_1. Then solve for m_2. Either way, the answer is the same (0.945g).

$$\ln\left(\frac{N_2}{N_1}\right) = -(1.54\times10^{-4} d^{-1})(365d) = -0.0562$$

$$\frac{N_2}{N_1} = e^{-0.0562} = 0.945 \qquad \text{therefore} \qquad \frac{m_2}{m_1} = 0.945$$

$$m_2 = 0.945m_1 = 0.945(1.00g) = 0.945g$$

(c) How much energy would be released by the decay described in part (b)? *[6 marks]*

Step 1: Calculate the number of tritium atoms that decayed ($m_{decayed} = m_{initial} - m_{left}$)

$$m_{decayed} = m_{initial} - m_{left} = 1.00g - 0.945g = 0.06g$$

$$N_{decayed} = m_{decayed} \times M_{H-3} = 0.06g \times \frac{1atom}{3.016049278u} \times \frac{1u}{1.660539\times10^{-27}kg} \times \frac{1kg}{1000g} = 1\times10^{22} atoms$$

Step 2: Calculate the energy released by one atom of ^3H decaying into one atom of ^3He.

$$\Delta E = \Delta mc^2$$

$$\Delta E = (3.016029319u - 3.016049278u)\left(\frac{1.660539\times10^{-27}kg}{1u}\right)\left(2.997925\times10^8 \tfrac{m}{s}\right)^2\left(\frac{1J}{1\frac{kg\cdot m^2}{s^2}}\right) = -2.9787\times10^{-15} J$$

Step 3: Calculate the energy released by all the atoms of ^3H that decayed into ^3He

$$\Delta E = N_{decayed} \times E_{perdecay} = (1\times10^{22} atoms)\left(-2.9787\times10^{-15} \tfrac{J}{atom}\right) = -3\times10^7 J$$

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So, 3×10^{7} J would be released over 1 year by the 1.00 g sample of ^{3}H.

17. Write a balanced chemical equation for the reaction of each of the following substances with water. Circle whether the resulting solution is acidic or basic. **[6 marks]**

Include states of matter for all products.

(a) $SO_{3(g)}$ + $H_2O_{(l)}$ acid or base?

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

(b) $Cs_{(s)}$ + $H_2O_{(l)}$ acid or base?

$\boxed{2Cs_{(s)} + 2H_2O_{(l)} \rightarrow 2CsOH_{(aq)} + H_{2(g)}}$ *or* $\boxed{2Cs_{(s)} + 2H_2O_{(l)} \rightarrow 2Cs^{+}_{(aq)} + 2OH^{-}_{(aq)} + H_{2(g)}}$

(c) Fe^{3+} + $H_2O_{(l)}$ acid or base?

$\boxed{Fe^{3+}_{(aq)} + 6H_2O_{(l)} \rightarrow [Fe(OH_2)_6]^{3+}_{(aq)}}$

18. As seen in class, Cs reacts much more violently with water than Na does. Use one of the three main periodic trends discussed in the 'periodic trends' section of the course to explain why this is the case. **[2 marks]**

When an alkali metal reacts with water, it loses an electron (to form the +1 cation). This requires energy input. Energy is released due to other parts of the reaction (especially formation of the very stable H_2 gas and solvation of the alkali metal cation by water molecules). If more energy must be used to remove the electron from the alkali metal then less energy will remain to be released and set the hydrogen gas on fire. ☺

Ionization energy measures the amount of energy required to remove an electron from a neutral atom (in the gas phase, but the trends still apply). The ionization energy is higher for smaller atoms in the same group because the electron being removed is closer to the nucleus and therefore held more tightly.

Since the ionization energy of Cs is lower than that of Na, less energy is used to form the Cs^{+} cation and more energy is therefore available to be violently released.

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

…AND THAT'S ALL FOR CHEM 1000.

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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

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

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

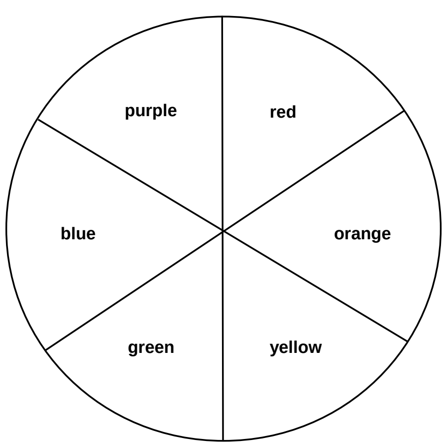
$\Delta E = \Delta mc^2$ $\qquad A = -\frac{\Delta N}{\Delta t}$ $\qquad A = kN$ $\qquad \ln\left(\frac{N_2}{N_1}\right) = -k(t_2 - t_1)$ $\qquad \ln(2) = k \cdot t_{1/2}$

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

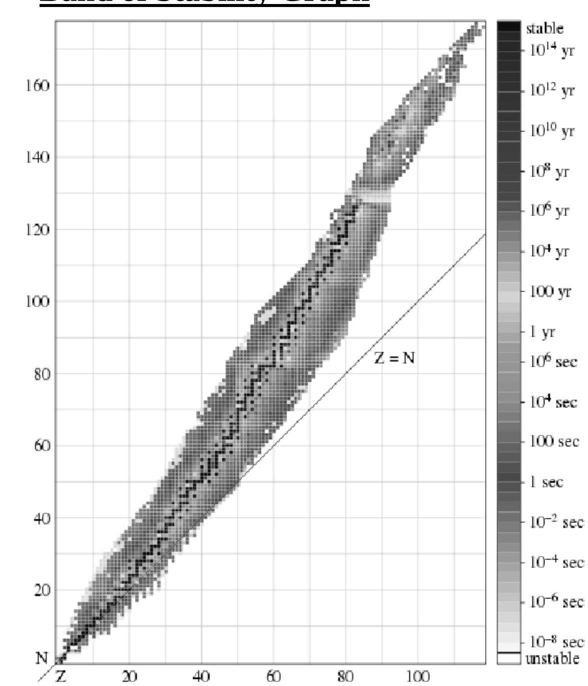
Spectrochemical Series

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

Isotope	**Mass**
^{3}H	3.016 049 278 u
^{3}He	3.016 029 319 u