Last Name: ______________________________

First name: ______________________________

Student Number: ______________________________

CHM 1311 A
Final Exam
December 2012

Professor: Dr. Fox

There are 15 pages in this test. A periodic table, data tables, and a formula sheet are provided at the end. You may rip these pages off of the exam and use them to cover your work. Any scratch work should be done on the back of these pages.

Please show all work to receive partial credit.

You have 180 minutes to complete the exam.

Good luck, and Happy Holidays!

Question	Points Possible	Points Earned	TA Initial
1	20		
2	10		
3	10		
4	10		
5	10		
6	10		
7	10		
8	10		
9	10		
TOTAL	100		

#1. (20 points) Short Answer Questions.

a) The number of atoms in 10.0 g of $CaCO_3$ (100.0 g/mol) is:

1.81×10^{23} 6.02×10^{22} 3.01×10^{23} 1.21×10^{23}

b) The solubility of cobalt (II) hydroxide is highest in a buffer solution with a pH of

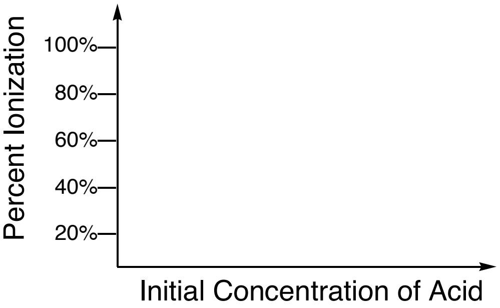
3.5 8.5 6.5 10.5

c) Balance the following reaction:

____ Fe (s) + ____ HCl (aq) → ____ $FeCl_3$ (s) + ____ H_2 (g)

When 4.55 g of Fe (s) was reacted with HCl (aq), 0.101 g of H_2 (g) was formed. The percent yield of the reaction is ____________________.

d) On the axes provided a right, draw a line (or curve) representing the percent ionization of a weak acid as a function of the initial concentration of the acid.



e) The standard heat of formation of solid potassium chlorate is -835 kJ. Write the chemical equation for the reaction to which this value applies.

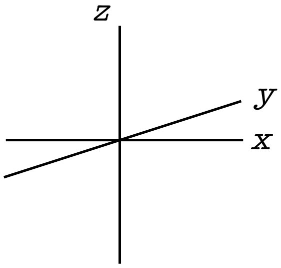
f) Find the overall balanced redox reaction (acidic conditions) from these half-reactions:

$Cu^{+} \rightarrow Cu^{2+}$

$BrO_2^{-} \rightarrow BrO^{-}$

OVERALL: ____

g) On the 3D axes provided at right, sketch an orbital that corresponds to the following set of quantum numbers: n = 2 and ℓ = 1.



h) One way to make a buffer is to start with a concentrated solution of a weak base and titrate it to the half-equivalence point with a strong acid. TRUE FALSE

i) For a given reaction, the plot of lnk versus 1/T yields a slope of - 13.9 and a y-intercept of 2.6×10^6. Knowing this information, the reaction has

$E_a > 0$ $\Delta H < 0$ $E_a < 0$ $\Delta H > 0$

j) Name two factors that influence the speed of a chemical reaction:

i) ____

ii) ____

k) Name the following compounds.

$Fe(OH)_3$ ______________________________

N_2O_5 ______________________________

l) Which of the following ions is the strongest base? F^- IO_3^- N_3^- CN^-

m) Write the equilibrium constant expression for the following reaction, and choose the best means by which you could encourage the formation of hydrogen gas.

n) $C(s) + H_2O(g) \leftrightarrows CO(g) + H_2(g)$ $\Delta H^o = 211$ kJ

i) Add steam and remove heat

ii) Increase volume and add heat

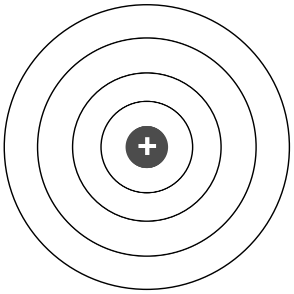
iii) Remove carbon monoxide and decrease volume

iv) Add hydrogen gas and increase volume

K =

o) A one litre balloon is filled with neon gas. A hole is made in the balloon and the gas effuses at a rate of 0.0106 mol/hr. If the same balloon is refilled with argon at the same pressure and temperature, its rate of effusion would be ________________.

p) On the Bohr Atom shown, draw an electronic transition that would correspond to the absorption of a photon with the longest wavelength.



#2.

a) (4 points) What is the minimum value of n for the following ℓ values and what is the maximum number of orbitals having these ℓ and n values?

$\ell = 1$

$\ell = 3$

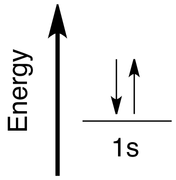
b) (2 points) How many electrons can be described by the each of the following sets of quantum numbers?

n = 3, $\ell = 2$

n = 3, $\ell = 3$, $m_\ell = -1$, $m_s = -1/2$

c) (4 points) Following the example of helium shown below, give the FULL spdf electronic configuration of silicon AND draw its orbital energy-level diagram.

Example: **Helium's spdf electronic configuration is $1s^2$ and its orbital energy-level diagram is:**



#3. In the Marion lab, you mix 25.0 g of CaO with exactly 80 mL of water at 25.0ºC and you observe the following reaction, as well as the release of some steam:

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$$

a) (4 points) What is the reagent in excess and how many grams of it will be left at the end of the reaction?

Reagent in excess: ________________ **Mass: ____________________**

b) (6 points) Using the data in the table below and on page 14, calculate the mass of the steam that escaped during the reaction.

CaO (s)	**ΔH_f^o = - 635 kJ/mol**
H_2O (l)	**ΔH_f^o = - 286 kJ/mol**
$Ca(OH)_2$ (s)	**ΔH_f^o = - 987 kJ/mol**

Answer: ______________________________

#4. The following reaction, occurring in a sealed vessel, has a percent yield of 94.9%:

$$2NaN_3\,(s) \rightarrow 2\,Na\,(l) + 3\,N_2(g)$$

a) (8 points) What volume of N_2, measured at 735 mmHg and 26.0ºC, is produced when 75.0 g of sodium azide decomposes?

Answer: ______________________

b) (2 points) After the reaction is complete, argon gas is added to the vessel until the final total pressure is 1000 mmHg. What is the mole fraction of nitrogen in the gas mixture?

Answer: ______________________

#5. You are provided 500.0 mL of a 0.100 M solution of $NaHCO_3$, which you will use to prepare a carbonate buffer with pH = 10.10. Your TA gives you a 0.300 M stock solution of H_2CO_3 and a jar of solid Na_2CO_3. (For H_2CO_3, $K_{a1} = 4.2x10^{-7}$ and $K_{a2} = 4.8x10^{-11}$)

a) (2 points) Which component, H_2CO_3 or Na_2CO_3, will you need to make the pH = 10.10 buffer? (Show your calculation to get the points, don't just guess!)

Circle needed component: H_2CO_3 Na_2CO_3

b) (4 points) How much of the needed component will you add to the 0.100 M $NaHCO_3$ solution to achieve the desired buffer pH? You may assume any volume change is negligible.

________________ mL of 0.300M H_2CO_3 *OR* _________________ g of Na_2CO_3

c) (4 points) What will be the new pH of the buffer if 0.0030 mol of HCl is added to it?

Answer: _____________________________

#6. The reaction of NO_2 and CO to make NO and CO_2 is believed to occur via a two-step mechanism:

$$NO_2 + NO_2 \rightarrow NO + NO_3$$
$$NO_3 + CO \rightarrow NO_2 + CO_2$$

a) (2 points) What is the overall reaction? What is the reaction intermediate?

b) (3 points) The rate law is determined experimentally to be: rate = $k[NO_2]^2$. Is the proposed mechanism reasonable? Why or why not? What would be the rate-determining step?

c) (5 points) When the initial concentration of NO_2 is 0.010 M, the initial rate of reaction is $5.5\text{x}10^{-6}$ M/s. What is the concentration of NO_2 after 3.00 min if the initial concentration is changed to 0.033 M?

Answer: ____________________________

#7.

a) (5 points) A student prepares a 0.120 M solution of an unknown monoprotic acid. At equilibrium, she measures the pH to be 3.820. What is the acid's ionization constant?

Answer: ___________________________

(b) (5 points) Vinegar is a dilute aqueous solution of acetic acid. The legal minimum acetic acid content of vinegar is 4.0% ***by mass*****. Dr. Fox takes a 5.00 mL sample of President's Choice brand vinegar and titrates it to completion with 38.08 mL of 0.1000 M NaOH. Does the sample exceed the minimum content? (Vinegar has a density of about 1.01 g/mL).**

Answer: ________________________

#8.

a) (3 points) What is the molar solubility of Ag_2SO_4 in pure water?

Answer: ___________________________

b) (3 points) What is the molar solubility of Ag_2SO_4 in 1.00 M Na_2SO_4?

Answer: ___________________________

c) (4 points) KIO_3 is added to 1.00 L of the solution formed in part (b), and we observe the formation of a precipitate, $AgIO_3$. Calculate the mass of KIO_3 (in mg) needed to start the precipitation.

Answer: ___________________________

#9. Indigo, the dye for blue jeans, has a percent composition, by mass, of 73.27% C, 3.84% H, 10.68% N, and the remainder is oxygen. the molecular mass of indigo is 262.3 u.

a) (5 points) What is the molecular formula of indigo?

Answer: ___________________________

b) (3 points) A 0.451 g sample of indigo undergoes complete combustion in a bomb calorimeter. It is found that the bomb calorimeter absorbs 264.8 J of heat during the reaction. What is the enthalpy of combustion, in kJ/mol, of indigo?

Answer: ___________________________

c) (2 points) What is the change in internal energy for the reaction in part (b)?

Answer: __________________________

Gas Laws

$PV = nRT$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_T = P_1 + P_2 + P_3 + \ldots$

$P_A = \chi_A P_T$

$$d = \frac{m}{V} = \frac{P \cdot MM}{RT}$$

$$E_K = \frac{1}{2}m\mathrm{v}^2$$

$$u_{rms} = \sqrt{\frac{3RT}{MM}}$$

$$\frac{Rate\ A}{Rate\ B} = \sqrt{\frac{MM_B}{MM_A}}$$

$$\left(\mathrm{P} + \frac{\mathrm{n^2a}}{\mathrm{V^2}}\right)(\mathrm{V} - \mathrm{nb}) = \mathrm{nRT}$$

Equilibrium

$K_P = K_C(RT^{)\Delta n}$

Acid/Base

$pOH = -\log[OH^-]$

$pH = -\log[H^+]$

$pH + pOH = 14$

$K_a \times K_b = K_W$

$pH = pK_a + \log [A^-]/[HA]$

$$pH = \frac{pK_{a1} + pK_{a2}}{2}$$

Thermochemistry

$\Delta U = q + W$

$W_{system} = -P\Delta V = -\Delta nRT$

$\Delta H = \Delta U + P\Delta V$

$q_P = \Delta U + P\Delta V$

$q = ms\Delta T$

$q = n\Delta H$

$\Delta H_{rxn}° = \sum n\Delta H_f°(pdts) - \sum n\Delta H_f°(rxts)$

The atom

$E = h\nu$

$c = \nu\lambda$

$E = -B/n^2$

Kinetics

$[A]_t = [A]_o - kt$

$\ln[A]_t = \ln[A]_o - kt$

$1/[A]_t = 1/[A]_o + kt$

$k = Ae^{(-Ea/RT)}$

$\ln(k_2/k_1) = (-Ea/R)(1/T_2 - 1/T_1)$

Other

$n = m/MM$

$C = n/V$

$$\%yield = \frac{actual\ yield}{theoretical\ yield} \times 100\%$$

$$\chi_A = \frac{n_A}{n_T}$$

Data For Water

Density = 1.00 g/mL (at 25°C)
$s = 2.13\ J\ g^{-1}\ K^{-1}$ (solid)
$s = 4.184\ J\ g^{-1}\ K^{-1}$ (liquid)
$s = 2.01\ J\ g^{-1}\ K^{-1}$ (gas)

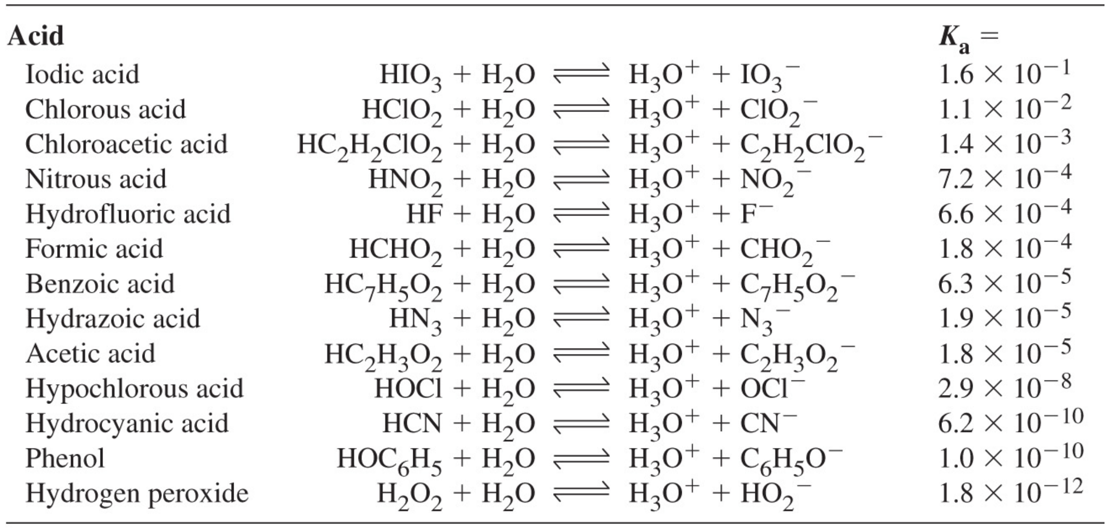
$K_W = 1.0x10^{-14}$
$\Delta H°_{fus} = 6.02\ kJ\ mol^{-1}$
$\Delta H°_{vap} = 40.7\ kJ\ mol^{-1}$

Constants and Conversion Factors

1 mmHg = 1 torr
760 mmHg = 1 atm
1 atm = 101.325 kPa
1 atm = 1.013125 bar
$1\ cm^3 = 1\ mL$
1000 mL = 1 L
$1000\ L = 1\ m^3$

Avogadro's Number	N	$6.022x10^{23}\ mol^{-1}$	
Faraday's constant	F	$96,485\ C{\cdot}mol^{-1}$	
Gas constant	R	$8.31451\ J{\cdot}K^{-1}{\cdot}mol^{-1}$	
	R	$0.08206\ atm{\cdot}L{\cdot}K^{-1}{\cdot}mol^{-1}$	
	R	$8.31451\ m^3Pa{\cdot}K^{-1}{\cdot}mol^{-1}$	
	R	$0.0831451\ bar\ L{\cdot}K^{-1}{\cdot}mol^{-1}$	
Planck's constant	h	$6.62608x10^{-34}$	J·s
Speed of Light	c	$2.99792458x10^{8}$	$m{\cdot}s^{-1}$

Table of Ionization Constants

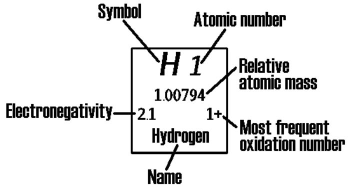


Acid		K_a =
Iodic acid	$HIO_3 + H_2O \rightleftharpoons H_3O^+ + IO_3^-$	1.6×10^{-1}
Chlorous acid	$HClO_2 + H_2O \rightleftharpoons H_3O^+ + ClO_2^-$	1.1×10^{-2}
Chloroacetic acid	$HC_2H_2ClO_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_2ClO_2^-$	1.4×10^{-3}
Nitrous acid	$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$	7.2×10^{-4}
Hydrofluoric acid	$HF + H_2O \rightleftharpoons H_3O^+ + F^-$	6.6×10^{-4}
Formic acid	$HCHO_2 + H_2O \rightleftharpoons H_3O^+ + CHO_2^-$	1.8×10^{-4}
Benzoic acid	$HC_7H_5O_2 + H_2O \rightleftharpoons H_3O^+ + C_7H_5O_2^-$	6.3×10^{-5}
Hydrazoic acid	$HN_3 + H_2O \rightleftharpoons H_3O^+ + N_3^-$	1.9×10^{-5}
Acetic acid	$HC_2H_3O_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$	1.8×10^{-5}
Hypochlorous acid	$HOCl + H_2O \rightleftharpoons H_3O^+ + OCl^-$	2.9×10^{-8}
Hydrocyanic acid	$HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$	6.2×10^{-10}
Phenol	$HOC_6H_5 + H_2O \rightleftharpoons H_3O^+ + C_6H_5O^-$	1.0×10^{-10}
Hydrogen peroxide	$H_2O_2 + H_2O \rightleftharpoons H_3O^+ + HO_2^-$	1.8×10^{-12}

Table of Selected Solubility Product Constants

Compound	K_{sp}	Compound	K_{sp}
$Mg(OH)_2$	1.2×10^{-11}	Ag_2CrO_4	1.9×10^{-12}
Ag_2SO_4	1.4×10^{-5}	$PbCrO_4$	1.8×10^{-14}
$CaSO_4$	9.1×10^{-6}	$BaCrO_4$	2.1×10^{-10}
$AgIO_3$	3.0×10^{-8}	Hg_2Cl_2	1.3×10^{-18}
PbI_2	8.7×10^{-9}	$BaSO_4$	1.1×10^{-10}
$PbCl_2$	1.9×10^{-5}	Ag_2CO_3	8.5×10^{-12}

Mokeur's Periodic table of the elements



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	*H 1* 1.00794 2.1 1+ Hydrogen																	*He 2* 4.002602 - - Helium
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium											**B 5** 10.811 2.0 3+ Boron	**C 6** 12.011 2.5 4+,4- Carbon	*N 7* 14.00674 3.0 3+,3- Nitrogen	*O 8* 15.9994 3.5 2- Oxygen	*F 9* 18.9984032 4.0 1- Fluorine	*Ne 10* 20.1797 - - Neon
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium											**Al 13** 26.981539 1.5 3+ Aluminum	**Si 14** 28.0855 1.8 4+ Silicon	**P 15** 30.973762 2.1 5+ Phosphorus	**S 16** 32.066 1.8 4+ Sulfur	*Cl 17* 35.4527 3.0 1- Chlorine	*Ar 18* 39.948 - - Argon
4	**K 19** 39.0983 0.8 1+ Potassium	**Ca 20** 40.078 1.0 2+ Calcium	**Sc 21** 44.955910 1.3 3+ Scandium	**Ti 22** 47.88 1.5 4+ Titanium	**V 23** 50.9415 1.6 5+ Vanadium	**Cr 24** 51.9961 1.6 3+ Chromium	**Mn 25** 54.93805 1.5 2+ Manganese	**Fe 26** 55.847 1.8 3+ Iron	**Co 27** 58.9332 1.8 2+ Cobalt	**Ni 28** 58.6934 1.8 2+ Nickel	**Cu 29** 63.546 1.9 2+ Copper	**Zn 30** 65.39 1.6 2+ Zinc	***Ga 31*** 69.723 1.6 3+ Gallium	**Ge 32** 72.61 1.6 4+ Germanium	**As 33** 74.92159 2.0 3+,3- Arsenic	**Se 34** 78.96 2.4 4+ Selenium	***Br 35*** 79.904 2.8 1- Bromine	*Kr 36* 83.80 - - Krypton
5	**Rb 37** 85.4678 0.8 1+ Rubidium	**Sr 38** 87.62 1.0 2+ Strontium	**Y 39** 88.90585 1.3 3+ Yttrium	**Zr 40** 91.224 1.4 4+ Zirconium	**Nb 41** 92.90638 1.6 5+ Niobium	**Mo 42** 95.94 1.8 6+ Molybdenum	Tc 43 98.9063 1.9 7+ Technetium	**Ru 44** 101.57 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium	**Pd 46** 106.42 2.2 2+ Palladium	**Ag 47** 107.8682 1.9 1+ Silver	**Cd 48** 112.411 1.7 2+ Cadmium	**In 49** 114.82 1.7 3+ Indium	**Sn 50** 118.71 1.8 4+ Tin	**Sb 51** 121.757 1.9 3+,3- Antimony	**Te 52** 127.60 2.1 4+ Tellurium	**I 53** 126.90447 2.5 1- Iodine	*Xe 54* 131.29 - - Xenon
6	***Cs 55*** 132.90543 0.7 1+ Cesium	**Ba 56** 137.327 0.9 2+ Barium	**La 57** 138.9055 1.1 3+ Lanthanum	**Hf 72** 178.49 1.3 4+ Hafnium	**Ta 73** 180.9479 1.5 5+ Tantalum	**W 74** 183.85 1.7 6+ Tungsten	**Re 75** 186.207 1.9 7+ Rhenium	**Os 76** 190.2 2.2 4+ Osmium	**Ir 77** 192.22 2.2 4+ Iridium	**Pt 78** 195.08 2.2 4+ Platinum	**Au 79** 196.96654 2.4 3+ Gold	***Hg 80*** 200.59 1.9 2+ Mercury	**Tl 81** 204.3833 1.8 1+ Thallium	**Pb 82** 207.2 1.8 2+ Lead	**Bi 83** 208.98037 1.9 3+ Bismuth	**Po 84** 208.9824 2.0 2+ Polonium	**At 85** 209.9871 2.2 1- Astatine	*Rn 86* 222.0176 - - Radon
7	***Fr 87*** 223.0197 0.7 1+ Francium	**Ra 88** 226.0254 0.9 2+ Radium	**Ac 89** 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Uun 110 269 - - Ununnilium	Uuu 111 272 - - Unununium	Uu 112 277 - - Ununbium		Uuq 114 289 - - Ununquadium		Uuh 116 289 - - Ununhexium		Uuo 118 293 - - Ununoctium

6	**Ce 58** 140.115 1.1 3+ Cerium	**Pr 59** 140.90765 1.1 3+ Praseodymium	**Nd 60** 144.24 1.1 3+ Neodymium	Pm 61 144.9127 1.1 3+ Promethium	**Sm 62** 150.36 1.2 3+ Samarium	**Eu 63** 151.965 1.2 3+ Europium	**Gd 64** 157.25 1.2 3+ Gadolinium	**Tb 65** 168.92534 1.2 3+ Terbium	**Dy 66** 162.50 1.2 3+ Dysposium	**Ho 67** 164.93032 1.2 3+ Holmium	**Er 68** 167.26 1.2 3+ Erbium	**Tm 69** 168.93421 1.2 3+ Thulium	**Yb 70** 173.04 1.1 3+ Ytterbium	**Lu 71** 174.967 1.2 3+ Lutetium
7	**Th 90** 232.0381 1.3 4+ Thorium	**Pa 91** 231.03588 1.5 5+ Protactinium	**U 92** 238.0289 1.4 6+ Uranium	Np 93 237.082 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.