Name: _____ Student Number: _____

Chemistry 1000 Final Exam
Version A
Fall 2018

INSTRUCTIONS

1) Read the exam carefully before beginning. There are 25 questions on pages 2 to 16 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	/ 18
2	/ 2
3	/ 4
4	/ 8
5	/ 6
6	/ 3
7	/ 8
8	/ 4
9	/ 2
10	/ 9

Q	Mark
11	/ 2
12	/ 7
13	/ 6
14	/ 6
15	/ 12
16	/ 6
17	/ 7
18	/ 8
19	/ 12
20	/ 4

Q	Mark
21	/ 8
22	/ 3
23	/ 10
24	/ 4
25	/ 1

Total	/ 160

Name: _____ Student Number: _____

1. Fill in each blank with the word or phrase that best completes the sentence. **[18 marks]**

(a) Carbon has two common neutral oxides: _____ is a good Lewis acid while _____ is a good Lewis base.

(b) The chemical formulas for the two allotropes of oxygen are _____ and _____.

(c) The names for three allotropes of carbon are:

_____

_____

_____

(d) The bonding in B_2H_6 is unusual because it contains bonds in which _____ electrons are shared by _____ atoms.

(e) Non-ideal gas behavior will eventually be observed if the _____ of the gas is sufficiently increased. Non-ideal effects are due to _____ and to _____.

(f) The element thallium (Tl) can form two different cations. The more common cation formed from thallium is Tl^+. The other cation formed from thallium is _____.

(g) In a co-ordination complex with _____ field ligands, the energy gap due to crystal field splitting is large. As such, the complex is more likely to be _____ spin.

(h) The fact that light can act as a particle (not just as a wave) was first demonstrated by the _____ experiment.

(i) Two isotopes of the same element contain the same number of _____ in their nuclei but different numbers of _____.

2. Circle the compounds in the following list that are reasonably soluble in water. **[2 marks]**
Marks will be deducted for adding incorrect circles.

Al_2O_3 $CaCl_2$ Na_2SO_4 $SrCO_3$ TiO_2

Name: _____ Student Number: _____

3. The "ABCs" of the periodic table. **[4 marks]**

Fill in the table below with the name and symbol for each element being described.

Information about the Element	Name	Symbol
Its name starts with the letter "A", and it is a noble gas.		
Its name starts with the letter "B", and it has a diagonal relationship with silicon.		
Its name starts with the letter "C", and a neutral atom has six valence electrons.		
Its name starts with the letter "D", and it is an isotope of hydrogen. *(Include the mass number for this symbol.)*		

4. Complete the table below by providing the missing name or chemical formula in each row. **[8 marks]**

Name	Formula
iron(III) chloride	
potassium sulfate	
hypochlorous acid	
carbonic acid	
	Cu_2O
	Na_2HPO_4
	H_2SO_3
	NH_3

Name: _____ Student Number: _____

5. Complete the table below by providing the ground-state electron configuration for each atom or ion as well as the number of valence electrons. **[6 marks]**

Use the noble gas notation, but always show all electrons in the valence shell explicitly.

Atom or ion	Electron configuration	Number of Valence Electrons
S^{2-}		
V		
V^{2+}		

6. A sample of lithium was analyzed by mass spectrometry. The sample was found to contain 6.421% ^{6}Li. The rest is ^{7}Li. What is the molar mass of lithium in **this** sample? **[3 marks]**

Table of Isotopic Masses

Isotope	Mass (u)
^{6}Li	6.015 122 8874
^{7}Li	7.016 003 437

Name: _____ Student Number: _____

7. Sketch each of the following orbitals on a set of labeled axes. **[8 marks]**
Your diagrams must show relative phase.

(a) $1s$ (b) $2p_y$

(c) $3d_{x^2-y^2}$ (d) $3d_{yz}$

8. For each of the following atomic orbitals, provide **one** valid set of quantum numbers. ***DO NOT*** *list every possible quantum number for that orbital.* **[4 marks]**

(a) $3d$ (b) $5p$

(c) $6s$ (d) $4f$

9. There is one quantum number discussed in CHEM 1000 that you should not have included in your answers to Question 8. Which quantum number is it? What is that quantum number used for? **[2 marks]**

Name: _____ Student Number: _____

10. Crystal field theory can be used to explain colour and magnetism of transition metal complexes. Answer the following questions regarding the $[Cu(H_2O)_6]^{2+}$ complex ion. **[9 marks]**

(a) Write the ground-state electron configuration for a neutral atom of Cu using noble gas notation. *[1 mark]*

(b) Write the ground-state electron configuration for Cu^{2+} using noble gas notation. *[1 mark]*

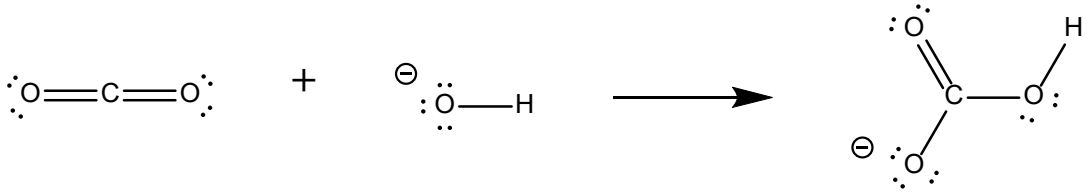
(c) What is the co-ordination number of the Cu^{2+} cation in this complex ion? *[1 mark]*

(d) Draw the crystal field splitting diagram for Cu^{2+} in this complex. Include electrons, and label each orbital. *[3 marks]*

(e) Would you expect the $[Cu(H_2O)_6]^{2+}$ complex ion to be coloured or colourless? Why? *[3 marks]*

Name: _____ Student Number: _____

11. The reaction of CO_2 with OH^- has an important role in biological blood pH regulation and the transportation of CO_2 in living systems. Complete the following equation by drawing in the curved arrows to show how the bicarbonate ion is formed. **[2 marks]**



12. Ionization energy generally increases across a period, but the ionization energy of aluminium is smaller than the ionization energy of magnesium. **[7 marks]**

(a) Explain why the ionization energies of atoms generally increase as we move from left to right across a period. Your answer should make it clear that you know what the term ionization energy means. *[3 marks]*

(b) Explain why the ionization energy of aluminium is smaller than the ionization energy of magnesium. *[4 marks]*

Name: _____ Student Number: _____

13. In the text that follows, cross out the incorrect word or words in each selection. **[6 marks]**

Each pair of words/phrases you are to choose between has been bolded and underlined.

A household water softener consists of a column packed with beads whose surfaces are covered in **anionic/cationic** groups. Initially, **calcium/sodium** ions are bound to the beads. As hard water flows over the beads, those ions are replaced by **monovalent/divalent** cations.

Regenerating the column is an application of **a diagonal relationship/ Le Chatelier's principle**. A highly concentrated solution of **calcium chloride/sodium chloride** is passed through the column, displacing the **calcium/sodium** ions that became bound to the column during the softening process.

14. **[6 marks]**

(a) Draw a Lewis diagram of AsF_3. Include any non-zero formal charges. *[1 mark]*

(b) Draw the three-dimensional structure of AsF_3, and name the molecular geometry. *[2 marks]*

(c) Is AsF_3 polar? If so, draw an arrow indicating the direction of the dipole moment vector. If not, show that the bond dipoles cancel out. *[2 marks]*

(d) What is the oxidation state of As in AsF_3? *[1 mark]*

Name: _____ Student Number: _____

15. **[12 marks]**

(a) Draw Lewis diagrams for all valid resonance structures of the nitrate ion (NO_3^-). *[4 marks]*
Include any non-zero formal charges.

(b) What is the N-O bond order in the nitrate ion? *[1 mark]*

(c) Name the molecular geometry of the nitrate ion. *[1 mark]*

(d) Draw a Lewis diagram for nitric acid (HNO_3). *[2 marks]*
Include any non-zero formal charges.

(e) How would the N-O bond lengths in nitric acid compare to the N-O bond lengths in the nitrate ion? *[2 marks]*

(f) Calculate the approximate pK_a value for nitric acid, and indicate whether it is a strong or weak acid. *[2 marks]*

Name: _____ Student Number: _____

16. Consider the following four substances: **[6 marks]**

CS_2 MgO NaF PCl_3

(a) Which of these substances are ionic compounds? *[1 mark]*

(b) List the four substances in order from highest to lowest boiling point: *[1 mark]*

highest _____ _____ _____ _____ lowest

(c) Justify your answer to part (b). *[4 marks]*

Name: _____ Student Number: _____

17. **[7 marks]**

(a) Draw a diagram of a Downs cell, used to make sodium metal. Make sure your diagram is clearly labeled, showing where the products are made, and how they are removed from the apparatus. *[3 marks]*

(b) Write the half-reactions that occur at each electrode of the Downs cell, as well as the overall reaction equation. *[3 marks]*

Anode:

Cathode:

Overall:

(c) A Downs cell is filled with a 1:2 mixture of sodium chloride and calcium chloride, and not with pure sodium chloride. Why? *[1 mark]*

Name: _____ Student Number: _____

18. Striking a match involves the combustion of $P_4S_{3(s)}$ to produce a white smoke of $P_4O_{10(s)}$ and sulfur dioxide gas:

$$P_4S_{3(s)} + 8\,O_{2(g)} \rightarrow P_4O_{10(s)} + 3\,SO_{2(g)}$$

Calculate the maximum volume of $SO_{2(g)}$ that can be produced from the complete combustion of 0.157 g $P_4S_{3(s)}$ at 20.0°C and 1.015 bar pressure. **[8 marks]**

Express your answer in mL.

Name: _____ Student Number: _____

19. Write balanced chemical reactions for each of the following processes. **[12 marks]**
Include states of matter.

(a) Sodium metal reacts with bromine.

(b) Potassium metal reacts with water.

(c) A strong acid is dropped onto calcium carbonate.

(d) Solid lithium carbonate is heated to a high temperature.

(e) Aluminium oxide reacts with hydroxide.

(f) Choose any metal that undergoes passivation in air, and write a balanced chemical reaction for passivation

20. Write balanced nuclear equations for each of the following processes. **[4 marks]**

(a) Electron capture by ^{59}Ni.

(b) Alpha decay of ^{223}Fr.

Name: _____ Student Number: _____

21. ^{90}Sr is a beta emitter. The beta particles produced by ^{90}Sr are used to gauge the thickness of manufactured parts in industrial settings: thicker parts block more beta particles. This works well for parts that are up to 3 mm thick. **[8 marks]**

(a) Write a balanced nuclear equation for beta emission by ^{90}Sr. *[2 marks]*

(b) A typical industrial ^{90}Sr source produces 120 MBq of activity. The half-life of this isotope is 29 years. How many atoms of ^{90}Sr does the source contain? *[4 marks]*

(c) Could we use an alpha emitter in thickness gauging? Why or why not? *[2 marks]*

22. If the root-mean-squared velocity in an argon gas is 851 m/s, what is the temperature of the gas? Calculations similar to this are used in some high-precision thermometry applications. **[3 marks]**

Name: _____ Student Number: _____

23. An excited hydrogen atom makes a transition from the $n = 5$ to the $n = 2$ energy level. **[10 marks]**

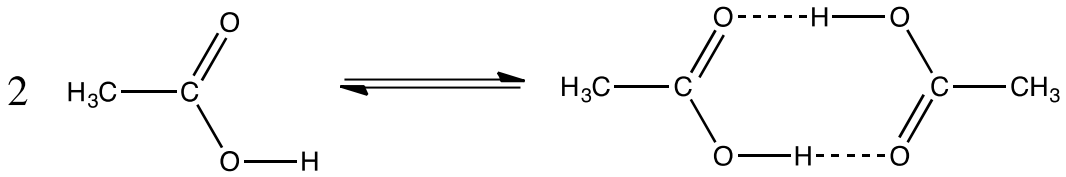
(a) What is the wavelength of the emitted photon? Choose an appropriate SI prefix so that your final answer is between 0.1 and 1000. *[8 marks]*

(b) What is the momentum of this photon? *[2 marks]*

Name: _____ Student Number: _____

24. In the gas phase, acetic acid (CH_3CO_2H) participates in the following equilibrium:

[4 marks]



Note that the drawings shown above are **not** complete Lewis diagrams.

(a) What is the name of the interaction that holds the dimers (the right-hand side of the equilibrium) together? *[1 mark]*

(b) What effect does this equilibrium have on the pressure of gaseous acetic acid? In other words, is the pressure higher or lower when some of the acetic acid molecules dimerize than it would have been if none of them did? Explain briefly, using a formula and a few words. *[3 marks]*

25. 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	$6.626\ 070 \times 10^{-34}$ $J{\cdot}Hz^{-1}$
Bohr radius (a_0)	$5.291\ 772 \times 10^{-11}$ m	Proton mass	1.007 277 u
Boltzmann constant (k_B)	$1.380\ 649 \times 10^{-23}$ $J{\cdot}K^{-1}$	Neutron mass	1.008 665 u
Electron charge (e)	$1.602\ 177 \times 10^{-19}$ C	Rydberg Constant (R_H)	$2.179\ 872 \times 10^{-18}$ J
Electron mass	$5.485\ 799 \times 10^{-4}$ u	Speed of light in vacuum	$2.997\ 925 \times 10^{8}$ $m{\cdot}s^{-1}$
Ideal gas constant (R)	$8.314\ 462$ $J{\cdot}mol^{-1}{\cdot}K^{-1}$	Standard atmospheric pressure	1 bar = 100 kPa
	$8.314\ 462$ $m^3{\cdot}Pa{\cdot}mol^{-1}{\cdot}K^{-1}$	Volume unit conversion	1000 L = 1 m^3

Formulae

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

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

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

$pK_a \approx 8 - 5p$ for oxoacids $O_pE(OH)_q$ or $(HO)_qEO_p$ $\quad N_2 = N_1\left(\frac{1}{2}\right)^{\Delta t/t_{1/2}}$

CHEM 1000 Standard Periodic Table

1																	18
1.0079 **H** 1	2											13	14	15	16	17	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**	(265) **Rf** 104	(268) **Db** 105	(271) **Sg** 106	(270) **Bh** 107	(277) **Hs** 108	(276) **Mt** 109	(281) **Ds** 110	(280) **Rg** 111	(285) **Cn** 112	(284) **Nh** 113	(289) **Fl** 114	(288) **Mc** 115	(293) **Lv** 116	(294) **Ts** 117	(294) **Og** 118

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	(262) **Lr** 103

Developed by Prof. R. T. Boeré (updated 2014)

DATA SHEET

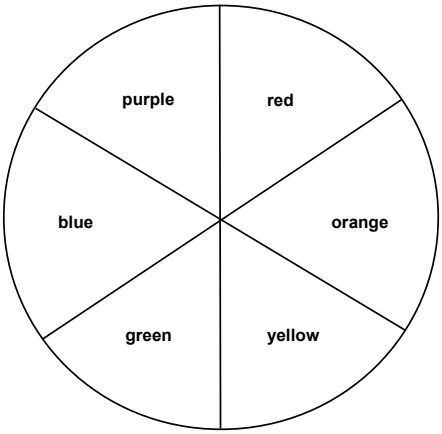
Spectrochemical Series

strong field weak field

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

Some Useful Masses

$^4_2\alpha$	4.001 506 179 u
^1_1p	1.007 276 467 u
^1_0n	1.008 664 916 u
$^0_{+1}\beta$	0.000 548 579 9 u
$^0_{-1}\beta$	0.000 548 579 9 u
^6_3Li	6.015 122 887 4 u
^7_3Li	7.016 003 437 u



Band of Stability Graph

The graph below shows the band of stability. The black dots represent all known stable isotopes.

