Carleton UNIVERSITY

FINAL
EXAMINATION
December 2016

P.W.

DURATION: 3 HOURS No. of Students: 580

Department Name & Course Number: CHEM 1101 A and B
Course Instructor(s) Pamela Wolff

AUTHORIZED MEMORANDA
CALCULATORS

Students MUST count the number of pages in this examination question paper before beginning to write, and report any discrepancy to a proctor. This question paper has **8** pages.

This examination question paper MAY be taken from the examination room.

In addition to this question paper, students require: an examination booklet **yes**
a Scantron sheet no

ANSWER ALL 10 QUESTIONS. EACH IS WORTH 10 MARKS. (THIS DOESN'T NECESSARILY MEAN YOU SHOULD SPEND THE SAME AMOUNT OF TIME ON EACH!)

- You may do the questions in any order
- You may detach the question pages (you don't need to hand in the exam paper)

PLEASE: **Space out your answers – if I can't read it, I can't give you marks for it**

Don't write in the margins – except the question number

- If you need an extra exam booklet, ***HOLD UP the one you have in the air*** – we'll bring you another.
- If you don't have a calculator, or have trouble with yours, ask for one; we have spares

DATA/EQUATIONS

$E = h\nu$

$E = hc/\lambda$

$E = R_H \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$

$PV = nRT$

$\left[P + \frac{an^2}{V^2}\right] [V - nb] = nRT$

$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H°_{vap}}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$

$\Delta T_b = K_b \, m \, \iota$

$\Delta T_f = K_f \, m \, \iota$

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G = \Delta G° + RT \ln Q$

$h = 6.626 \times 10^{-34}$ J·s

$c = 3.00 \times 10^{8}$ m/s

$R_H = 2.18 \times 10^{-18}$ J

R = 0.08206 L·atm/K·mol

= 8.314 J/K·mol

T(K) = T(°C) + 273

K_b (H_2O) = 0.52 °C/m

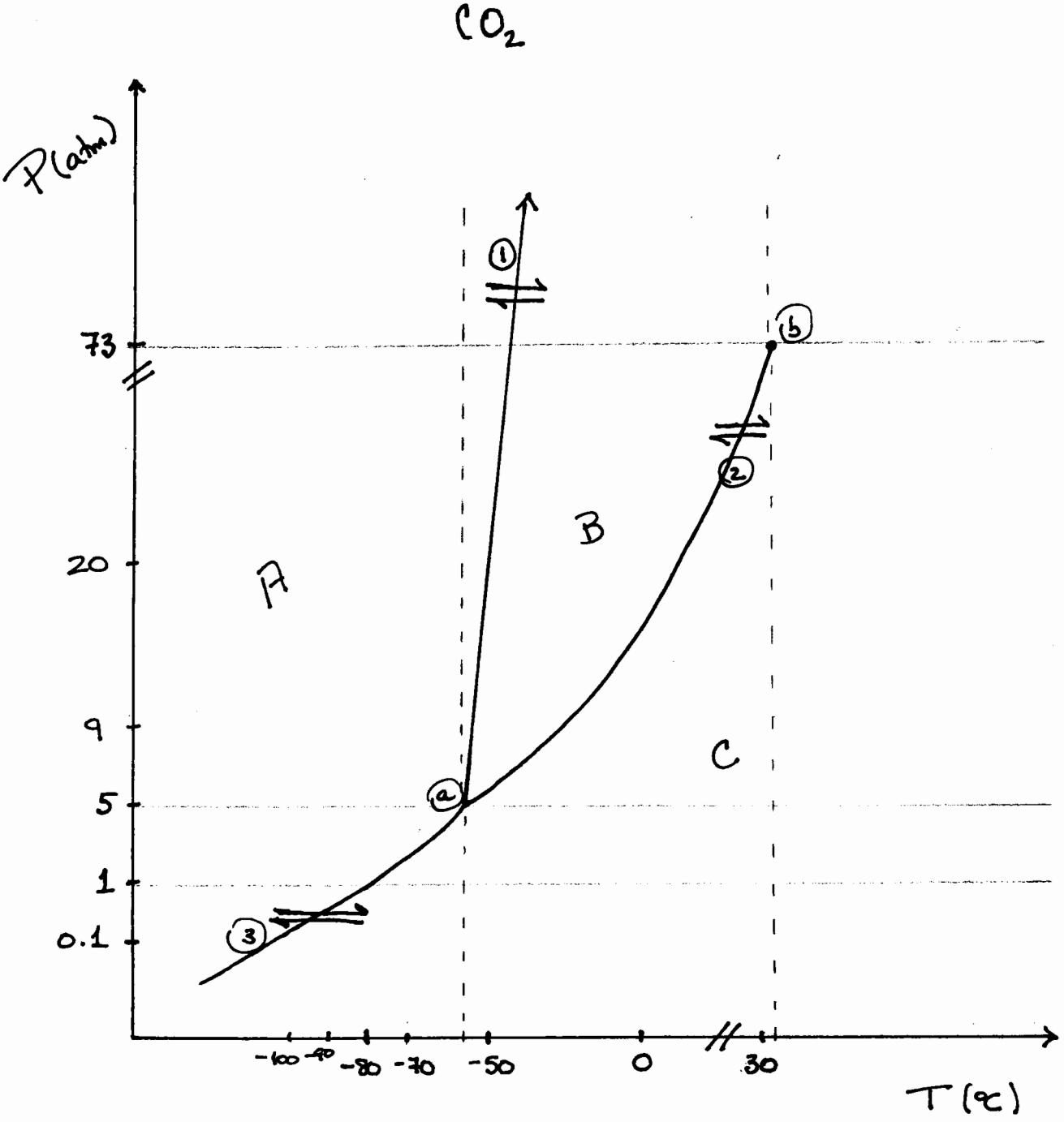
K_f (H_2O) = 1.86 °C/m

Avogadro's number: 6.02×10^{23}

	$\Delta H_f°$ (kJ/mol) 25 °C	S° (J/K mol) 25 °C	$\Delta G_f°$ (kJ/mol) 25 °C
$Cu_{(s)}$	0	33.2	0
$CuO_{(s)}$	–157	42.7	–129.7
$H_2O_{(l)}$	–285.8	69.9	–237.1
$H_2O_{(g)}$	–241.8	188.7	–228.7
$NH_{3(g)}$	–45.9	193	–16.4
$N_{2(g)}$	0	191.6	0
$Na_{(s)}$	0	51.3	0
$NaN_{3(s)}$	21.3	70.5	0.36

Enjoy your holiday break!

PHASE DIAGRAM: CO_2



Axes are not linear

Q. 3. 4

CHEMISTRY CHEM 1101 A & B
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The periodic table

www.webelements.com

PERIODIC TABLE

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 **H** 1.008																		Helium 2 **He** 4.0026
Lithium 3 **Li** 6.94	Beryllium 4 **Be** 9.0122												Boron 5 **B** 10.81	Carbon 6 **C** 12.011	Nitrogen 7 **N** 14.007	Oxygen 8 **O** 15.999	Fluorine 9 **F** 18.998	Neon 10 **Ne** 20.180
Sodium 11 **Na** 22.990	Magnesium 12 **Mg** 24.305												Aluminium 13 **Al** 26.982	Silicon 14 **Si** 28.085	Phosphorus 15 **P** 30.974	Sulfur 16 **S** 32.06	Chlorine 17 **Cl** 35.45	Argon 18 **Ar** 39.948
Potassium 19 **K** 39.098	Calcium 20 **Ca** 40.078(4)		Scandium 21 **Sc** 44.956	Titanium 22 **Ti** 47.867	Vanadium 23 **V** 50.942	Chromium 24 **Cr** 51.996	Manganese 25 **Mn** 54.938	Iron 26 **Fe** 55.845(2)	Cobalt 27 **Co** 58.933	Nickel 28 **Ni** 58.693	Copper 29 **Cu** 63.546(3)	Zinc 30 **Zn** 65.38(2)	Gallium 31 **Ga** 69.723	Germanium 32 **Ge** 72.63	Arsenic 33 **As** 74.922	Selenium 34 **Se** 78.96(3)	Bromine 35 **Br** 79.904	Krypton 36 **Kr** 83.798(2)
Rubidium 37 **Rb** 85.468	Strontium 38 **Sr** 87.62		Yttrium 39 **Y** 88.906	Zirconium 40 **Zr** 91.224(2)	Niobium 41 **Nb** 92.906(2)	Molybdenum 42 **Mo** 95.96(2)	Technetium 43 **Tc** [97.91]	Ruthenium 44 **Ru** 101.07(2)	Rhodium 45 **Rh** 102.91	Palladium 46 **Pd** 106.42	Silver 47 **Ag** 107.87	Cadmium 48 **Cd** 112.41	Indium 49 **In** 114.82	Tin 50 **Sn** 118.71	Antimony 51 **Sb** 121.76	Tellurium 52 **Te** 127.60(3)	Iodine 53 **I** 126.90	Xenon 54 **Xe** 131.29
Caesium 55 **Cs** 132.91	Barium 56 **Ba** 137.33	57-70 *	Lutetium 71 **Lu** 174.97	Hafnium 72 **Hf** 178.49(2)	Tantalum 73 **Ta** 180.95	Tungsten 74 **W** 183.84	Rhenium 75 **Re** 186.21	Osmium 76 **Os** 190.23(2)	Iridium 77 **Ir** 192.22	Platinum 78 **Pt** 195.08	Gold 79 **Au** 196.97	Mercury 80 **Hg** 200.59	Thallium 81 **Tl** 204.38	Lead 82 **Pb** 207.2	Bismuth 83 **Bi** 208.98	Polonium 84 **Po** [208.98]	Astatine 85 **At** [209.99]	Radon 86 **Rn** [222.02]
Francium 87 **Fr** [223.02]	Radium 88 **Ra** [226.03]	89-102 **	Lawrencium 103 **Lr** [262.11]	Rutherfordium 104 **Rf** [265.12]	Dubnium 105 **Db** [268.13]	Seaborgium 106 **Sg** [271.13]	Bohrium 107 **Bh** [270]	Hassium 108 **Hs** [277.15]	Meitnerium 109 **Mt** [276.15]	Darmstadtium 110 **Ds** [281.16]	Roentgenium 111 **Rg** [280.16]	Copernicium 112 **Cn** [285.17]	Ununtrium 113 **Uut** [284.18]	Flerovium 114 **Fl** [289.19]	Ununpentium 115 **Uup** [288.19]	Livermorium 116 **Lv** [293]	Ununseptium 117 **Uus** [294]	Ununoctium 118 **Uuo** [294]

Key:
Element Name
Atomic number
Symbol
Atomic weight (mean relative mass)

*lanthanoids	Lanthanum 57 **La** 138.91	Cerium 58 **Ce** 140.12	Praseodymium 59 **Pr** 140.91	Neodymium 60 **Nd** 144.24	Promethium 61 **Pm** [144.91]	Samarium 62 **Sm** 150.36(2)	Europium 63 **Eu** 151.96	Gadolinium 64 **Gd** 157.25(3)	Terbium 65 **Tb** 158.93	Dysprosium 66 **Dy** 162.50	Holmium 67 **Ho** 164.93	Erbium 68 **Er** 167.26	Thulium 69 **Tm** 168.93	Ytterbium 70 **Yb** 173.05
**actinoids	Actinium 89 **Ac** [227.03]	Thorium 90 **Th** 232.04	Protactinium 91 **Pa** 231.04	Uranium 92 **U** 238.03	Neptunium 93 **Np** [237.05]	Plutonium 94 **Pu** [244.06]	Americium 95 **Am** [243.06]	Curium 96 **Cm** [247.07]	Berkelium 97 **Bk** [247.07]	Californium 98 **Cf** [251.08]	Einsteinium 99 **Es** [252.08]	Fermium 100 **Fm** [257.10]	Mendelevium 101 **Md** [258.10]	Nobelium 102 **No** [259.10]

Symbols and names: the symbols and names of the elements, and their spellings are those recommended by the International Union of Pure and Applied Chemistry (IUPAC - http://www.iupac.org/). Names have yet to be proposed for elements 113, 115, 117, and 118 and so those used here are IUPAC's temporary systematic names. In some countries, the spellings **aluminum**, **cesium**, and **sulphur** are usual.
Group labels: the numeric system (1–18) used here is the current IUPAC convention.
Atomic weights (mean relative masses): these are the IUPAC 2009 values and given to 5 significant figures. The last significant figure of each value is considered reliable to ±1 except where a larger uncertainty is given in parentheses. Representative values for those elements having an atomic weight interval are given (H, Li, B, C, N, O, Si, S, Cl, Tl). Elements for which the atomic weight is given within [brackets] have no stable nuclides and are represented by the element's longest lived isotope reported in the IUPAC 2009 values.

1. Electromagnetic radiation with a wavelength of 276 nm has just enough energy to overcome the work function in chromium metal.
   a) Calculate the work function in kJ/mol.
   b) If electromagnetic radiation with a wavelength of 132 nm strikes chromium, calculate the kinetic energy that *each* emitted electron will have, in joules.

2. a) Give the electron configuration of copper, Cu.
   b) List the valence subshell(s) of copper, and give the orbital diagram, and the quantum numbers of the electron(s) in it.
   c) List the highest energy subshell of copper, and give the orbital diagram, and the quantum numbers of the electron(s) in it.
   d) Give the electron configuration of the copper (I) ion.

3. Predict the most likely ion or ions for the following and give their electron configurations:
   a) I
   b) Sn
   c) Sb
   d) Sr

4. a) Draw and label a band diagram for an exactly 50/50 mixture of Ga and As
   b) Draw and label a band diagram for a mixture of Ga and As that has a very slight excess of Ga. Indicate what type of extrinsic semiconductor this is.

5. Ethanol has a standard heat of vaporization of 39.3 kJ/mol.
   a) At 22 °C, it has a vapour pressure of 0.0767 atm. Determine its normal boiling point, in Celsius.
   b) If you measure a vapour pressure of 0.25 atm in a container of ethanol, what is its temperature in Celcius?

6. Using the phase diagram of carbon dioxide with the data sheets:
   a) Label regions A, B, and C, lines 1, 2, and 3, and points a and b. (*Use the letters and numbers given on the diagram and answer in your exam booklet* ***or*** *give a sketch of the diagram.* ***Don't write it on the question paper; I don't want that handed in!****)*
   b) Describe **in POINT FORM** what happens when the pressure of the CO_2 is raised from 1 atm to 70 atm at a temperature of 0°C. Make reasonable pressure and temperature estimates as needed.
   c) Describe **in POINT FORM** what happens when CO_2 is heated from −100°C to 30°C at a pressure of 8 atm. Make reasonable estimates as needed.
   d) Give an estimate of the normal sublimation point of CO_2

7. You have a 4.15 M solution of magnesium sulfate $MgSO_4$ which has a density of 1.43 g/ml.
   a) Given the data on the data page, determine its normal boiling point.
   b) If you had a solution of magnesium iodide with exactly the same molarity, would you expect its normal boiling point to be higher or lower than the magnesium sulfate solution? Explain briefly (a few words is plenty)

8. Calcium phosphate (a fertilizer) can be synthesized by the reaction:

$$Ca(NO_3)_{2\,(aq)} + Na_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2\,(s)} + NaNO_{3\,(aq)}$$

a) Calculate the mass of calcium phosphate produced, ***in kilograms,*** if 190.0 kg of calcium nitrate react with 125.0 kg of sodium phosphate. ***Show enough work to justify your answer.***

b) If the percent yield of the reaction was found to be 97.3%, calculate the actual mass of calcium phosphate that was produced, in kilograms.

9. Copper metal can be produced from copper(II) oxide according to the reaction:

$$3\ CuO_{(s)} + 2\ NH_{3\,(g)} \rightarrow 3\ Cu_{(s)} + 3\ H_2O_{(l)} + N_{2(g)}$$

Using the table of thermodynamic at the front of the exam:

a) Calculate the standard state enthalpy of the reaction

b) Calculate the standard state entropy of the reaction

c) Calculate the standard state free energy of the reaction at 25°C

d) Determine the temperature range over which the reaction is spontaneous at standard state

10. Automobile airbags are inflated by the reaction (in part; other things are going on in the airbag as well. Ignore those for this question!):

$$2\ NaN_{3(s)} \rightarrow 2\ Na_{(s)} + 3\ N_{2(g)}$$

Using the table of thermodynamic at the front of the exam:

a) Calculate the standard state free energy of the reaction at 325°C

b) Calculate the free energy of the reaction at 325°C when the pressure of the nitrogen gas is 1.34 atm (typical as an airbag deploys)