Exam 4 Chm 205 (Dr Mattson) 29 April 2015

Academic Integrity Pledge: *In keeping with Creighton University's ideals and with the Academic Integrity Code, I pledge that this work is my own and that I have neither given nor received inappropriate assistance in preparing it.*

Signature:

Name:

Circle your section: **Section A** or **Section C**

Circle your Folder group:

H He Li Be B C N O F Ne Na Mg Al Si

Instructions: Show all work whenever a calculation box is provided! Write legibly. Include units whenever appropriate. You will receive credit for **how** you worked each problem as well as for the correct answer. If you need more space, you may use the back of the data sheet provided — Write: "See Data Sheet" in the answer box. On your desk you are allowed only pencils (but no pencil pouch), an eraser, and a non-programmable calculator without a slipcover. Backpacks and bags must be closed and on the floor under the table. Cell phones must be OFF and placed in your backpack/bag – not in your pocket.

1. Sulfuric acid is an extremely useful chemical. Globally, it ranks #1 in terms of quantity produced. It is used in mineral processing, fertilizer manufacturing, oil refining, wastewater processing, and chemical synthesis. Sulfuric acid is made by a sequence of three individual reactions, starting with the combustion of sulfur.

Rxn 1. $S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta H^o = -297$ kJ

$\Delta S^o = +11$ J/K

Rxn 2. $2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$ $\Delta H^o = -198$ kJ

$\Delta S^o = -187$ J/K

Rxn 3. $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$ $\Delta H^o = -132$ kJ

$\Delta S^o = -170$ J/K

1a. (4 pts) Which reaction(s) is/are non-spontaneous at all temperatures?

Circle: **Rxn 1** or **Rxn 2** or **Rxn 3** or **None of these**

Which reaction(s) is/are spontaneous at all temperatures?

Circle: **Rxn 1** or **Rxn 2** or **Rxn 3** or **None of these**

Which reaction(s) is/are spontaneous at low T and non-spontaneous at high T?

Circle: **Rxn 1** or **Rxn 2** or **Rxn 3** or **None of these**

Which reaction(s) is/are spontaneous at high T and non-spontaneous at low T?

Circle: **Rxn 1** or **Rxn 2** or **Rxn 3** or **None of these**

1b. (4 pts) Calculate the amount of heat produced or consumed, q, when 405 g sulfur dioxide reacts with excess oxygen as shown in Reaction 2.

Answer with units: _____

1c. (4 pts) Calculate ΔG^o_{rxn} for Reaction 2.

Answer with units: _____

1d. (4 pts) Calculate K_p at 298 K for Reaction 2.

Answer: _____

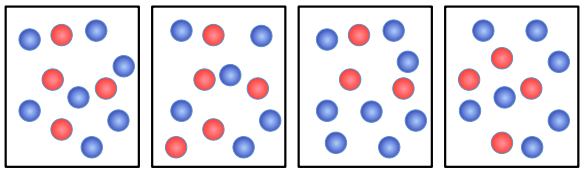
1e. (4 pts) Calculate ΔG_{rxn} for Reaction 2 at 298 K if you started with $P_{SO_2} = 0.010$ atm, $P_{O_2} = 0.020$ atm, and $P_{SO_3} = 1.0$ atm. Express your answer in kJ

Answer with units: _____

1f. (4 pts) At what temperature does Reaction 3 become spontaneous or non-spontaneous? (If you believe this does not happen based on your answer to Question 1a, explain why it does not happen.)

Answer with units: _____

2. These are solutions of Red(aq) and Blue(aq). Solution A is at equilibrium, Red ⇌ Blue



A **B** **C** **D**

2a. (3 pts) What is the sign of ΔG_{rxn} for Red → Blue for each of the solutions B, C, and D?

Solution B. ΔG_{rxn} is < 0, = 0, or >0

Solution C. ΔG_{rxn} is < 0, = 0, or >0

Solution D. ΔG_{rxn} is < 0, = 0, or >0

2b. (3 pts) What is the numerical value for ΔG^o_{rxn}?

Answer: _____

3. (5 pts) Sulfur dioxide can be purchased as a liquid. It vaporizes at 263 K.

3a. What is the sign of ΔH_{vap} for the vaporization of $SO_2(l)$? Circle: **ΔH_{vap} <0** or **>0**

3b. What is the sign of ΔS_{vap} for the vaporization of $SO_2(l)$? Circle: **ΔS_{vap} <0** or **>0**

3c. What is the sign of ΔG^o_{vap} for the vaporization of $SO_2(l)$? Circle: **ΔG^o_{vap} <0** or **> 0** or **= 0**

3d. What is the sign of ΔG_{vap} for the vaporization of $SO_2(l)$ at 250 K? Circle: **ΔG_{vap} <0** or **>0** or **= 0**

3e. What is the sign of ΔG_{vap} for the vaporization of $SO_2(l)$ at 263 K? Circle: **ΔG_{vap} <0** or **>0** or **= 0**

4. (4 pts) Balance this oxidation-reduction reaction with smallest whole-numbered coefficients in acidic solution:

$$Cr + NO_3^- \rightarrow Cr^{3+} + NO_2$$

5a. (4 pts) Co^{2+} reacts spontaneously with which of the following six? Circle all that apply.

Cd^{2+} Zn^{2+} Pb^{2+} Cd Zn Pb

5b. (2 pts) Which pair of half reactions is most spontaneous? Circle TWO half reactions.

$Cd|Cd^{2+}$ $Zn|Zn^{2+}$ $Pb|Pb^{2+}$ $Co|Co^{2+}$ $Cu|Cu^{2+}$

6. (4 pts) Referring to the Table of Standard Reduction Potentials on your data sheet, what is the…

6a. easiest species to reduce?
6b. easiest species to oxidize?
6c. best oxidizing agent?
6d. best reducing agent?

7a. (3 pts) What is E^o for galvanic cell $Cu|Cu^{2+}||Ag^+|Ag$. Show your work!

Answer with units: _____

7b. (2 pts) Balance the oxidation-reduction reaction referred to in Question 7a.

7c. (4 pts) Calculate $[Ag^+]$ given that $[Cu^{2+}] = 1.00$ M and E = 0.48 v.

Answer: _____

7d. (4 pts) With passing time, what happens to the…

mass of the anode? Decreases or Increases
concentration of Ag^+? Decreases or Increases
value of E^o? Increases or Decreases or No change
value of E? Increases or Decreases or No change

7e. (4 pts) What is the numerical value for ΔG^o_{rxn}?

Answer with units: _____

7f. (4 pts) What is the numerical value for K_c?

Answer: _____

8. (6 pts) Bismuth exists with only one stable isotope, ^{209}Bi. One of the following isotopes decays by β-emission and the other by positron emission. Predict which is which by balancing these reactions.

8a. $^{211}_{83}Bi \rightarrow$
8b. $^{203}_{83}Bi \rightarrow$

8c. Another isotope, ^{187}Bi, has a half-life of 0.035 s and decays by an α-emission instead. Balance the reaction.

$^{187}_{83}Bi \rightarrow$

9. (4 pts) Carbon-14 decays with a half-lift of 5730 years, which makes $k = 1.21 \times 10^{-4}$ yr^{-1}. How old is a sandal, made of plant material, found at an archaeology site if the decay rate (disintegrations per hr per g C) was 74% of that of living matter.

Answer: _____

Exam Subtotal:	Folder (20 max):	Total:
_____	_____	_____

A ≥ 90; B+ ≥ 85; B ≥ 80; C+ ≥ 75; C ≥ 70; D ≥ 60

Table of Standard Reduction Potentials

	E^o (V)
$Cl_2 + 2\ e^- \rightarrow 2Cl^-$	1.36
$O_2 + 4\ H^+ + 4\ e^- \rightarrow 2H_2O$	1.23
$Br_2 + 2\ e^- \rightarrow 2Br^-$	1.09
$Ag^+ + e^- \rightarrow Ag$	0.80
$I_2 + 2\ e^- \rightarrow 2\ I^-$	0.54
$O_2 + 2\ H_2O + 4\ e^- \rightarrow 4\ OH^-$	0.40
$Cu^{2+} + 2\ e^- \rightarrow Cu$	0.34
$2H^+ + 2\ e^- \rightarrow H_2$	0.00
$Fe^{3+} + 3\ e^- \rightarrow Fe$	-0.036
$Pb^{2+} + 2\ e^- \rightarrow Pb$	-0.13
$Sn^{2+} + 2\ e^- \rightarrow Sn$	-0.14
$Ni^{2+} + 2\ e^- \rightarrow Ni$	-0.26
$Co^{2+} + 2\ e^- \rightarrow Co$	-0.28
$PbSO_4 + 2\ e^- \rightarrow Pb + SO_4^{2-}$	-0.35
$Cd^{2+} + 2\ e^- \rightarrow Cd$	-0.40
$Fe^{2+} + 2\ e^- \rightarrow Fe$	-0.44
$Cr^{3+} + e^- \rightarrow Cr^{2+}$	-0.50
$Cr^{3+} + 3\ e^- \rightarrow Cr$	-0.73
$Zn^{2+} + 2\ e^- \rightarrow Zn$	-0.76
$2\ H_2O + 2\ e^- \rightarrow H_2 + 2OH^-$	-0.83
$Al^{3+} + 3\ e^- \rightarrow Al$	-1.66
$Mg^{+2} + 2\ e^- \rightarrow Mg$	-1.66
$Na^+ + e^- \rightarrow Na$	-2.71
$Ca^{2+} + 2\ e^- \rightarrow Ca$	-2.76
$Ba^{2+} + 2\ e^- \rightarrow Ba$	-2.90
$K^+ + e^- \rightarrow K$	-2.92
$Li^+ + e^- \rightarrow Li$	-3.05

Useful equations for Thermodynamics:

$\Delta G^o = \Delta H^o - T\Delta S^o$

$\Delta G = \Delta H - T\Delta S$

$\Delta G = \Delta G^o + R\ T\ \ln Q$ $\quad R = 8.314$ J/mol K

$\Delta G^o = -\ R\ T\ \ln K$

Useful equations for Electrochemistry:

$E = E^o - {}^{0.0592}/_{n} \log Q = E^o - {}^{R\ T}/_{n\ F} \log Q$

$E^o = {}^{0.0592}/_{n} \log K = {}^{R\ T}/_{n\ F} \ln K$

$\Delta G = -nFE$ $\quad \Delta G^o = -nFE^o$

1 F = 96500 coul = 1 mol e^- = 96500 J/mol V

Charge (coul) = current (amps) x time(s)

Useful equations for Nuclear Chemistry:

$\ln({}^{N_o}/_{N_t}) = kt$ $\quad t_{1/2} = 0.693/k$

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																1 H 1.01	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 97	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Ti 204.37	82 Pb 207.2	83 Bi 208.98	84 Po 209	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226.03	89 Ac 227															

Answers

1a. i. **None of these; ii. Rxn 1**; iii. **Rxn 2** and **Rxn 3**; iv. **None of these**

1b. q = -626 kJ

1c. -142 kJ

1d. $K_p = 8 \times 10^{24}$

1e. $\Delta G_{rxn} = -109$ kJ

1f. 776 K

2a. Solution B. $\Delta G_{rxn} < 0$; Solution C. $\Delta G_{rxn} > 0$; Solution D. $\Delta G_{rxn} = 0$

2b. $\Delta G^o_{rxn} = -1.4$ kJ

3a. ΔH_{vap} **>0**; 3b. ΔS_{vap} **>0**; 3c. $\mathbf{\Delta G^o_{vap} < 0}$; 3d. $\mathbf{\Delta G_{vap} > 0}$; 3e. $\mathbf{\Delta G_{vap} = 0}$

4. $6\ H^+ + Cr + 3\ NO_3^- \rightarrow Cr^{3+} + 3\ NO_2 + 3\ H_2O$

5a. Cd Zn

5b. $Zn|Zn^{2+}\ Cu|Cu^{2+}$

6a. Cl_2; 6b. Li; 6c. Cl_2; 6d. Li

7a. $E^o = +0.46$ v

7b. $2\ Ag^+ + Cu \rightarrow Cu^{2+} + 2\ Ag$

7c. 2.18 M

7d. Decreases; Decreases; No change; Decreases

7e. $\Delta G^o_{rxn} = -89$ kJ

7f. (4 pts) What is the numerical value for $K_c = 3.6 \times 10^{15}$

8a. $^{211}_{83}Bi \rightarrow {}^{0}_{-1}Bi + {}^{211}_{84}Po$; 8b. $^{203}_{83}Bi \rightarrow {}^{0}_{+1}Bi + {}^{203}_{82}Pb$; 8c. $^{187}_{83}Bi \rightarrow {}^{4}_{2}\alpha + {}^{183}_{81}Tl$

9. 2500 y