Chem 1142—Exam 4A
Spring 2011

Name: KEY

Multiple Choice. [4 pts. Each]
Circle the best response.

Q1. A certain chemical reaction has ΔH^o = +32 kJ/mol and ΔS^o = 78.0 J/mol·K. When does this reaction proceed spontaneously?

a) The reaction is never spontaneous
b) The reaction is only spontaneous at low temperatures
c) The reaction is always spontaneous
d) The reaction is only spontaneous at high temperatures

Q2. An example of a reaction that is likely to have a large and positive value of ΔS^o is:

a) $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$
b) $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$
increase in #gas molecules! →
c) $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$
d) $2O_3(g) \longrightarrow 3O_2(l)$
e) $CO_2(g) + H_2(g) \longrightarrow CO(g) + H_2O(g)$

Q3. Methanol has a freezing point of –94 °C. Pick the correct set of values for ΔH, ΔS, and ΔG at a temperature of –91 °C for the process: methanol(s) $\longrightarrow$ methanol(l)

	ΔH	ΔS	ΔG
a	+	–	0
b	–	–	+
c	+	+	–
d	+	+	+
e	–	–	–

solid → liq (fusion) always requires heat ⇒ $\Delta H > 0$
$\Delta S > 0$, since liquid is more "disordered" than solid.
$\Delta G < 0$, because melting is spontaneous @ temp above mp!

$$\Delta G^o = -RT\ln K \Rightarrow K = e^{-\Delta G^o/RT} = e^{\frac{+3200\ \mathrm{J/mol}}{8.3145\frac{\mathrm{J}}{\mathrm{mol\cdot K}} \times 298\mathrm{K}}} = 3.64$$

Q4. What is the equilibrium constant of a reaction with ΔG^o = –3.2 kJ/mol at a temperature of 298 K?

a) 3.64 b) 0.275 c) 950 d) 0.990 e) 0.288

Q5. Calculate E^o_{cell} for the following electrochemical cell: $E^o_{cell} = E^o_{RHS} - E^o_{LHS} = 0.80V - 0V = +0.80V$

$Pt(s)|H^+(aq, 1M)|H_2(g, 1\ atm)||Ag^+(aq, 1M)|Ag(s)$

a) 1.60 V b) 0.80 V c) 0.00 V d) –0.80 V e) –1.60 V

↑ note: list of electrode potentials was given on this exam from our textbook.

Q6. Where does oxidation occur in an electrochemical cell?

a) Anode b) Salt Bridge c) Voltmeter d) Cathode e) Faraday

Q7. How many moles of electrons flow when an electrical current of 13.0 A flows for 2.00 minutes?

a) 26.0 mol b) 6.50 mol c) 1.5 x 10^8 mol d) 0.108 mol e) 0.0162 mol

$Q = I \cdot t = 13.0\,A \times 2.00\,min = 13.0\frac{C}{s} \times 120\,s = 1560\,C$

mol e^-? $1560\,C \times \frac{1\,mol\,e^-}{96{,}500\,C} = 0.0162\,mol\,e^-$

↑ Faraday's constant

Short Response Questions. Show ALL work to receive credit.

Q8. [15 pts.] Balance the following redox reaction using the ½ reaction method. Be sure to clearly identify the oxidation numbers of all atoms/ions in this reaction.

$$\overset{(0)}{Zn}(s) + \overset{(+4)}{V}\overset{(-2)}{O}^{2+}(aq) \longrightarrow \overset{(+2)}{V}^{2+}(aq) + \overset{(+2)}{Zn}^{2+}(aq)$$

oxidation: $Zn \rightarrow Zn^{2+} + 2e^-$

reduction: $VO^{2+} \rightarrow V^{2+}$

$VO^{2+} \longrightarrow V^{2+} + H_2O$ (balance O)

$2H^+ + VO^{2+} \longrightarrow V^{2+} + H_2O$ (balance H)

$2e^- + 2H^+ + VO^{2+} \longrightarrow V^{2+} + H_2O$ (balance charge)

Overall: $Zn \rightarrow Zn^{2+} + 2e^-$

$2e^- + 2H^+ + VO^{2+} \rightarrow V^{2+} + H_2O$

$\oplus$ $Zn + 2H^+ + VO^{2+} \longrightarrow Zn^{2+} + V^{2+} + H_2O$

Q9. [10 pts.] The chemical reaction: $3H_2(g) + N_2(g) \longrightarrow 2NH_3(g)$ has a value of ΔG^o equal to –33.2 kJ/mol at a temperature of 25 °C. If the partial pressures of H_2, N_2, and NH_3 are 0.0320 atm, 0.290 atm, and 48.0 atm respectively, then calculate ΔG for this reaction. What does this value of ΔG tell you about the reaction?

$\Delta G = \Delta G^\circ + RT \ln Q$

$Q = P_{NH_3}^2 / P_{H_2}^3 \times P_{N_2} = 48.0^2 / 0.0320^3 \times 0.290 = 2.4\underline{2}5 \times 10^8$

$\Rightarrow \Delta G = -33{,}200 \text{ J/mol} + 8.3145 \text{ J/mol·K} \times 298 \text{ K} \times \ln(2.4\underline{2}5 \times 10^8)$

$= -33{,}200 \text{ J/mol} + 47{,}\underline{8}36 \text{ J/mol}$

$= +14.6 \text{ kJ/mol}$

(NON-SPONTANEOUS if $\Delta G > 0$)

(but... reverse rxn will be spont)

Q10. [10 pts.] How many grams of Al(s) can be formed from the electrolysis of molten aluminum bromide, using a current of 182 A for a time period of 432 minutes?

$AlBr_3(l) = Al^{3+}(l) + 3Br^-(l)$

rxn: $3e^- + Al^{3+} \longrightarrow Al$

$\Rightarrow 3\text{mol } e^- = 1\text{mol Al}$

$Q = I \cdot t = 182\,C/s \times 432\,\text{min} \times \frac{60s}{1\,\text{min}} = 4.717 \times 10^6\,C$

#mol e^-? $4.717 \times 10^6\,C \times \frac{1\,\text{mol } e^-}{96{,}500\,C} = 48.89\,\text{mol } e^-$

Al? $48.89\,\text{mol } e^- \times \frac{1\,\text{mol Al}}{3\,\text{mol } e^-} \times \frac{26.98\,g\,Al}{1\,\text{mol Al}} = 440.\,g\,Al$

Q11. [13 pts.] A chemical reaction has a value of ΔG^o equal to –12.0 kJ/mol at a temperature of 23 °C (→ 296K), and a value of ΔG^o equal to –9.90 kJ/mol at a temperature of 48 °C (→ 321K). Calculate ΔS^o for this reaction.

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

$$\left.\begin{aligned} &\Rightarrow \Delta G_1^\circ = \Delta H^\circ - T_1 \Delta S^\circ \\ &\Rightarrow \Delta G_2^\circ = \Delta H^\circ - T_2 \Delta S^\circ \end{aligned}\right\} \ominus$$

$\Rightarrow \Delta G_1^\circ - \Delta G_2^\circ = (T_2 - T_1)\Delta S^\circ$

$\Rightarrow \Delta S^\circ = \frac{\Delta G_1^\circ - \Delta G_2^\circ}{T_2 - T_1} = \frac{-12{,}000\,J/mol \ominus -9{,}900\,J/mol}{321K - 296K}$

$\Rightarrow \boxed{\Delta S^\circ = -84.0\,\frac{J}{mol \cdot K}}$

Q12. [10 pts.] Write formulas for the following compounds:

a) lithium phosphate: Li_3PO_4

b) ammonium sulfate: $(NH_4)_2SO_4$

c) calcium sulfate trihydrate: $CaSO_4 \cdot 3H_2O$

d) perchloric acid: $HClO_4$

e) heptanitrogen disulfide: N_7S_2

Q13. [10 pts.] What is the molar solubility of lead(II) fluoride in a solution of 0.10 M NaF(aq)? ↰ 0.10 M F^- (common ion)
K_{sp} (PbF_2) = 4.1 x 10^{-8}.

$$PbF_2(s) \rightleftharpoons Pb^{2+}(aq) + 2F^-(aq)$$

	$PbF_2(s)$	Pb^{2+}	F^-
I	—	0	0.10
C	"−s"	+s	+2s
E	—	(s)	(0.10 + 2s)

$$K_{sp} = [Pb^{2+}][F^-]^2_{eq}$$

$$\Rightarrow 4.1\times10^{-8} = (s)(0.10+2s)^2 \approx (s)(0.10)^2 \quad \text{assuming } s \ll 0.10$$

$$\Rightarrow s = \frac{4.1\times10^{-8}}{0.10^2} = 4.1\times10^{-6}\,M \quad \text{(so, assumption was valid!)}$$

BONUS QUESTIONS. (Show all work to receive full credit.)

1. [2 pts.] Polonium-210 (Po) undergoes alpha decay. Write out the balanced nuclear reaction for this process.

$${}^{210}_{84}Po \longrightarrow {}^{4}_{2}He + {}^{206}_{82}Pb \qquad (\alpha\text{-particle} = {}^{4}_{2}He)$$

−balance Z, A

2. [3 pts.] Name the following coordination compound:

(+3)
$[Cr(NH_3)_4Cl_2]Br$

tetraammine dichloro chromium(III) bromide

3. [3 pts.] Strontium-90 is a beta-emitter, with a half-life of 30. years. How many grams of strontium-90 will remain out of a 32 g sample that is 120 years old?

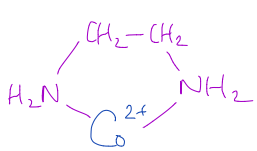
$$\frac{120}{30.} = 4 \text{ half lives!}$$

$$32\text{g} \times \tfrac{1}{2} \times \tfrac{1}{2} \times \tfrac{1}{2} \times \tfrac{1}{2} = 2.0\text{g}$$

4. [2 pts.] What is meant by the term: **bidentate ligand**? Be as specific as you can.

It can form 2 coordinate covalent bonds to a metal!

ex: "en" = $H_2\ddot{N}-CH_2-CH_2-\ddot{N}H_2$



Useful Information

$\Delta G = -nFE_{cell}$ $\Delta G^{o} = -nFE^{o}_{cell}$ $E^{o}_{cell} = \dfrac{RT}{nF}\ln K$

$E_{cell} = E^{o}_{cell} - \dfrac{RT}{nF}\ln Q$ $E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode}$ $F = 96{,}500\ \mathrm{C/mol\ e^{-}}$

$R = 8.3145\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$ $Q\ (\text{charge}) = I \cdot t$ $\Delta G = \Delta H - T\Delta S$

$\Delta S = q/T$ $\Delta G = \Delta G^{\circ} + RT\ln Q$ $\Delta G^{\circ} = -RT\ln K$

Periodic Table of the Elements

IA 1	IIA 2	3	4	5	6	7	8	9	10	11	12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIIA 18
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 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92160	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 [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba* 137.33	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po [210]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra** [226]	103 Lr [262]	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [265]	109 Mt [268]	110 [269]	111 [272]	112 [277]	113	114 [285]	115	116 [289]	117	118 [293]

*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
**	89 Ac [227]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]

Table 19.1 Standard Reduction Potentials at 25°C*

Half-Reaction	$E°$(V)
$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$	+2.87
$O_3(g) + 2H^+(aq) + 2e^- \longrightarrow O_2(g) + H_2O$	+2.07
$Co^{3+}(aq) + e^- \longrightarrow Co^{2+}(aq)$	+1.82
$H_2O_2(aq) + 2H^+(aq) + 2e^- \longrightarrow 2H_2O$	+1.77
$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O$	+1.70
$Ce^{4+}(aq) + e^- \longrightarrow Ce^{3+}(aq)$	+1.61
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \longrightarrow Au(s)$	+1.50
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O$	+1.33
$MnO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Mn^{2+}(aq) + 2H_2O$	+1.23
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O$	+1.23
$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$	+1.07
$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O$	+0.96
$2Hg^{2+}(aq) + 2e^- \longrightarrow Hg_2^{2+}(aq)$	+0.92
$Hg_2^{2+}(aq) + 2e^- \longrightarrow 2Hg(l)$	+0.85
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$	+0.68
$MnO_4^-(aq) + 2H_2O + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$	+0.59
$I_2(s) + 2e^- \longrightarrow 2I^-(aq)$	+0.53
$O_2(g) + 2H_2O + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	+0.34
$AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$	+0.22
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow SO_2(g) + 2H_2O$	+0.20
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	+0.15
$Sn^{4+}(aq) + 2e^- \longrightarrow Sn^{2+}(aq)$	+0.13
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$	−0.25
$Co^{2+}(aq) + 2e^- \longrightarrow Co(s)$	−0.28
$PbSO_4(s) + 2e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$	−0.31
$Cd^{2+}(aq) + 2e^- \longrightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	−0.44
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	−0.74
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	−0.76
$2H_2O + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \longrightarrow Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$	−1.66
$Be^{2+}(aq) + 2e^- \longrightarrow Be(s)$	−1.85
$Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$	−2.37
$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \longrightarrow Ca(s)$	−2.87
$Sr^{2+}(aq) + 2e^- \longrightarrow Sr(s)$	−2.89
$Ba^{2+}(aq) + 2e^- \longrightarrow Ba(s)$	−2.90
$K^+(aq) + e^- \longrightarrow K(s)$	−2.93
$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.05

Increasing strength as oxidizing agent

Increasing strength as reducing agent

*For all half-reactions the concentration is 1 *M* for dissolved species and the pressure is 1 atm for gases. These are the standard-state values