Key

Name (please print)

CHEMISTRY 128
HOUR TEST 3
June 27, 2003

USEFUL INFORMATION:

$R = 8.314$ J/K*mole

1 amp $= 1$ C/s

$F = 96{,}500$ C/mol

$\Delta S_{surroundings} = -\Delta H/T$

$\Delta S^{o}_{system} = \Sigma S^{o}_{prod} - \Sigma S^{o}_{react}$

$\Delta H^{o}_{reaction} = \Sigma H^{o}_{prod} - \Sigma H^{o}_{react}$

$\Delta G^{o}_{reaction} = \Sigma G^{o}_{prod} - \Sigma G^{o}_{react}$

$\Delta G^{o}_{system} = \Delta H^{o}_{system} - T\Delta S^{o}_{system}$

$\Delta G_{system} = \Delta G^{o}_{system} - RT\ln Q$

$\Delta G^{o}_{system} = -RT\ln K$

$E^{o}_{cell} = E^{o}_{red} + E^{o}_{ox}$

$\Delta G^{o}_{system} = -nFE^{o}_{cell}$

$E_{cell} = E^{o}_{cell} - (0.0592/n)\log Q$

$\log K = (nE^{o}_{cell})/0.0592$

1 IA																	18 VIIIA
1 H 1.008	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	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	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 ⌐	9 VIIIB	10 ¬	11 IB	12 IIB	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 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.30
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 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.40	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 137.34	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po 210	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226.03	103 Lr 262.1	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt									

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 146.92	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 239.05	95 Am 241.06	96 Cm 247.07	97 Bk 249.08	98 Cf 251.08	99 Es 254.09	100 Fm 257.10	101 Md 258.10	102 No 255

There Are 7 Pages On This Test Including This Cover Page.
The Test Contains 100 Points.

Part I. (44 points) Short Answers

1. A bottle of liquid bromine contains a considerable volume of bromine vapor at room temperature.

   a. Write a balanced chemical equation for the vaporization of liquid bromine.

   $Br_2(\ell) \rightarrow Br_2(g)$

   b. ΔH is (**positive, zero, negative**) for the vaporization of liquid bromine

   c. ΔS is (**positive, zero, negative**) for the vaporization of liquid bromine

   d. The vaporization is (**less, more**) favorable as the temperature is raised.

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

$\Delta G = (+) - T(+)$

2. The Third Law of Thermodynamics deals with (**Gibb's Free energy, enthalpy , entropy**).

3. The First Law of Thermodynamics deals with (**Gibb's Free energy, generic energy , entropy**).

4. What type of molecular motion is the extension and compression of a chemical bond?

   vibrational motion

5. In Na_2SO_4 the oxidation state of Na is (**+6, +3, +1, – 1, -3, -6**) and the oxidation state of S is (**+6, +3, +1, – 1, -3, -6**).

ox. state = +4

6. The oxidation state of N in NO_2 is (**more positive than, the same as, less positive than**) the oxidation state of N in N_2 and would therefore need to be (**oxidized, reduced**) to be converted into N_2.

ox. state = zero

7. Considering the following half-reactions:

$Mg^{2+} + 2\,e^- \rightarrow Mg\,(s)$ $\quad E^\circ_{red} = -2.37$ V

$Al^{3+} + 3\,e^- \rightarrow Al\,(s)$ $\quad E^\circ_{red} = -1.66$ V

   a. Which species is most easily oxidized (at standard conditions)? Mg

   b. Which species is the strongest oxidizing agent (at standard conditions)? Al^{3+}

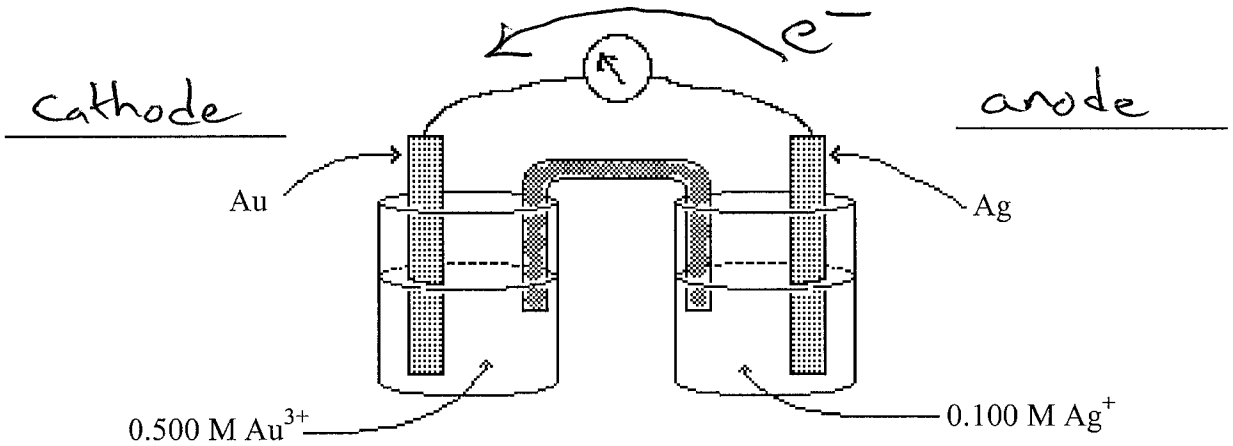
8. On the cell diagram below:

   a. Label the cathode and the anode.

   b. Use an arrow to indicate the direction in which electrons will flow.

$Ag^+ (aq) + 1\ e^- \rightarrow Ag\ (s)$ $\quad E^\circ_{red} = 0.80\ V$

$Au^{3+} (aq) + 3\ e^- \rightarrow Au\ (s)$ $\quad E^\circ_{red} = 1.50\ V$



Part II. (8 points) Balance the following reaction that occurs in acid: (show method clearly for full credit)

$$Cr_2O_7^{2-} (aq) + Fe^{2+} (aq) \rightarrow Cr^{3+} (aq) + Fe^{3+} (aq)$$

$$14\ H^+ + 6e^- + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$$

$$[Fe^{2+} \rightarrow Fe^{3+} + 1e^-] \times 6$$

$$14\ H^+ + Cr_2O_7^{2-} + 6\ Fe^{2+} \rightarrow 2\ Cr^{3+} + 7\ H_2O + 6\ Fe^{3+}$$

Part III. Problems (48 points) **Show all calculations for full credit.** No calculations, no credit.

10. (12 points) What mass (in grams) of solid $Pb(OH)_2$ ($K_{sp} = 1.40 \times 10^{-15}$) will dissolve in 0.750 L of an aqueous solution that has a pH of 11.35.

$$Pb(OH)_2(s) \rightleftharpoons Pb^{2+}(aq) + 2OH^-(aq)$$

Initial		2.24×10^{-3}
Change	$+y$	$+2y$
Equil	y	$2.24 \times 10^{-3} + 2y$

$[OH^-]_{initial} = 10^{-pOH} = 10^{-2.65} = 2.24 \times 10^{-3}$

$pOH = 14 - pH = 14 - 11.35 = 2.65$

$K_{sp} = [Pb^{2+}][OH^-]^2$

$1.40 \times 10^{-15} = [y][2.24 \times 10^{-3} + 2y]^2$

$1.40 \times 10^{-15} = [y][2.24 \times 10^{-3}]^2$ Assuming y is small

$$y = [Pb^{2+}] = \frac{1.40 \times 10^{-15}}{[2.24 \times 10^{-3}]^2} = 2.79 \times 10^{-10} \text{ M}$$

Checking the approximation.... % Ionization $= \left(\frac{2.79 \times 10^{-10}}{2.24 \times 10^{-3}}\right) 100 = 1.25 \times 10^{-5}\%$

Mass of $Pb(OH)_2 = 2.79 \times 10^{-10} \frac{\text{mol } Pb^{2+}}{1\text{L}} \times \frac{1 \text{ mol } Pb(OH)_2}{1 \text{ mol } Pb^{2+}} \times \frac{241.23 \text{ g}}{1 \text{ mol } Pb(OH)_2} \times \frac{0.750\text{L}}{1} = 5.05 \times 10^{-8}$ g $Pb(OH)_2$

11. (14 points) Consider the following reaction:

$$8\ H_2S\ (g) + 4\ O_2\ (g) \leftrightarrow 8\ H_2O\ (l) + S_8\ (s) \qquad \Delta H^\circ_{rxn} = -2122\ kJ$$

Given the following information, determine the ΔG°_f (in kJ/mol) of H_2S (g) at 25.0°C.

Species	S° (J/mol.K)	ΔG°_f (kJ/mol)
H_2S (g)	205.8	???
O_2 (g)	205.2	0.000
H_2O (l)	69.95	-237.1
S_8 (s)	256.8	0.000

$$\Delta S^\circ_{system} = \sum S^\circ(product) - \sum S^\circ(reactant)$$

$$\Delta S^\circ_{reaction} = [8\ S^\circ(H_2O) + S^\circ(S_8)] - [8\ S^\circ(H_2S) + 4\ S^\circ(O_2)]$$

$$= [8(69.95) + 256.8] - [8(205.8) + 4(205.2)]$$

$$= -1650.8\ \frac{J}{K}$$

$$\Delta G^\circ_{Reaction} = \Delta H^\circ_{reaction} + T\Delta S^\circ_{reaction}$$

$$= -2122\ kJ + (298K)\left(-1650.8\ \frac{J}{K} \times \frac{1\ kJ}{1000\ J}\right)$$

$$= -1630\ kJ$$

$$\Delta G^\circ_{reaction} = \sum \Delta G^\circ_f(products) - \sum \Delta G^\circ_f(reactants)$$

$$\Delta G^\circ_{reaction} = [8\Delta G^\circ_f(H_2O) + \Delta G^\circ_f(S_8)] - [8\Delta G^\circ_f(H_2S) + 4\Delta G^\circ_f(O_2)]$$

$$-1630\ kJ = [8(-237.1) + 0] - [8\ \Delta G^\circ_f(H_2S) + 4(0)]$$

$$-1630\ kJ = -1896.8\ kJ - 8\ \Delta G^\circ_f(H_2S)$$

$$+266.8\ kJ = -8\ \Delta G^\circ_f(H_2S)$$

$$-33.35\ \frac{kJ}{mol} = \Delta G^\circ_f(H_2S)$$

12. (14 Points) Consider the following electrochemical cell at 25°C.

$$Al(s) \mid Al^{3+}\ (???? M) \parallel Fe^{2+}\ (0.50\ M) \mid Fe\ (s)$$

$Al^{3+}(aq) + 3\ e^- \rightarrow Al(s)$ $\quad E^\circ_{red} = -1.660\ V$

$Fe^{2+}(aq) + 2\ e^- \rightarrow Fe(s)$ $\quad E^\circ_{red} = -0.440\ V$

a. Write the balanced equation for this cell as it is written.

$3\,[Fe^{2+} + 2e^- \rightarrow Fe]$ $\quad \mathcal{E}^\circ_{red} = -0.44V$

$2\,[Al \rightarrow Al^{3+} + 3e^-]$ $\quad \mathcal{E}^\circ_{ox} = +1.66V$

$3\,Fe^{2+}(aq) + 2Al(s) \rightarrow 3\,Fe(s) + 2Al^{3+}(aq)$ $\quad \mathcal{E}^\circ_{cell} = 1.22V$

b. Calculate the ε°_{cell} for the cell as it is written.

c. The cell potential (ε_{cell}) was experimentally measured to be 1.240 V. Determine the $[Al^{3+}]$ (in M).

$$E_{cell} = E^\circ_{cell} - \frac{0.0592}{n} \log Q$$

$$1.24V = 1.22V - \frac{0.0592}{6} \log \frac{[Al^{3+}]^2}{[Fe^{2+}]^3}$$

$$-2.03 = \log \frac{[Al^{3+}]^2}{[0.50]^3}$$

$$10^{-2.03} = \frac{[Al^{3+}]^2}{[0.50]^3}$$

$$\sqrt{(0.125)(0.00937)} = [Al^{3+}] = 3.4 \times 10^{-2}\ M$$

d. Calculate the value of ΔG° (in kJ) for the reaction of this cell.

$$\Delta G^\circ = -n\mathcal{F} E^\circ_{cell} = -(6)\left(96{,}500\ \frac{C}{mol}\right)\left(1.22\ \frac{J}{C}\right)\left(\frac{1\ kJ}{1000\ J}\right)$$

$$= -706.4\ kJ$$

e. Does this reaction favor the formation of products or reactants?

Products

13. (8 points) Chlorine is produced commerically by the electrolysis of aqueous sodium chloride. The anodic reaction is

$$2\ Cl^-(aq) \rightarrow Cl_2(g) + 2\ e^-$$

If a current of 53.7 A is used, how much time (in hours) is required to produce 355 g of Cl_2?

$$355\ g\ Cl_2 \times \frac{1\ mol\ Cl_2}{70.91\ g\ Cl_2} \times \frac{2\ mole^-}{1\ mol\ Cl_2} \times \frac{96{,}500\ C}{1\ mol\ e^-} \times \frac{1\ s}{53.7\ C} \times \frac{1\ hr}{3600\ s} = 5.48\ hrs$$