# Chem. 6C Midterm 1

Version A

October 19, 2007

Name_____

Student Number _____

All work must be shown on the exam for partial credit. Points will be taken off for incorrect or no units. Non graphing calculators and one hand written 3" × 5" note card are allowed.

| | |
|---|---|
| **Problem 1** (of 15 possible) | |
| **Problem 2** (of 26 possible) | |
| **Problem 3** (of 20 possible) | |
| **Problem 4** (of 15 possible) | |
| **Problem 5** (of 6 possible) | |
| **Problem 6** (of 28 possible) | |
| **Problem 7** (of 10 possible) | |
| **Problem 8** (of 21 possible) | |
| **Problem 9** (of 9 possible) | |
| **Midterm Total** (of 150 possible) | |

I would like my grade to be posted on line by my student number

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1) Answer the questions below using the following data

| Half Reaction | $E^o$ (V) |
|---|---|
| $Ag^{2+}(aq) + e^- \rightarrow Ag^+(aq)$ | 1.99 |
| $Au^{3+}(aq) + 3e^- \rightarrow Au(s)$ | 1.50 |
| $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ | 0.77 |
| $2H^+(aq) + 2e^- \rightarrow H_2(g)$ | 0.00 |
| $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ | -0.126 |
| $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ | -0.23 |
| $Al^{3+}(aq) + 3e^- \rightarrow Al(s)$ | -1.66 |
| $Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$ | -2.76 |

(3 pts) Which is the strongest reducing agent? Ca(s)

(3 pts) Which is the strongest oxidizing agent? $Ag^{2+}(aq)$

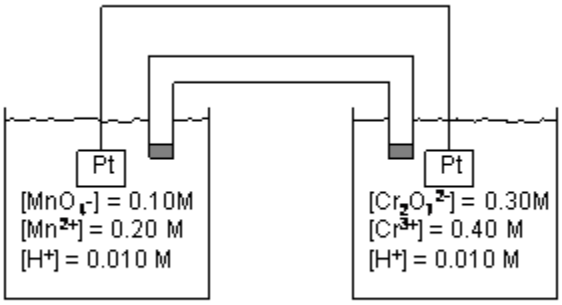
(3 pts) Will Al(s) dissolve in 1 $mol \cdot L^{-1}$ HCl? Yes

(3 pts) Can Pb(s) reduce $Ag^{2+}(aq)$? Yes

(3 pts) In the electrochemical cell $Ni(s)|Ni^{2+}(aq)||Au^{3+}(aq)|Au(s)$. What is the emf when the cell is at equilibrium?

At equilibrium the emf = 0 V

2) Answer the following questions using the given galvanic cell




$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ $E^o = 1.51$ V
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ $E^o = 1.33$ V

(3 pts) When current is allowed to flow what species is oxidized?
$Cr^{3+}$

(2 pts) What is the value of $E^o_{cell}$?
1.51 V – 1.33 V = 0.18 V

(3 pts) What is the oxidation state of Cr in $Cr_2O_7^{2-}$?
6+

(5 pts) What is the balanced equation of this cell?
$6(MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l))$
$5(2Cr^{3+}(aq) + 7H_2O(l) \rightarrow Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-)$
$6MnO_4^-(aq) + 10Cr^{3+}(aq) + 11H_2O(l) \rightarrow 6Mn^{2+}(aq) + 5Cr_2O_7^{2-}(aq) + 22H^+(aq)$

(4 pts) What is the value of Q, reaction quotient, for this cell reaction?

$Q = ([Mn^{2+}]^6[Cr_2O_7^{2-}]^5[H^+]^{22})/([MnO_4^-]^6[Cr^{3+}]^{10})$
$= ((0.20)^6(0.30)^5(0.010)^{22})/((0.10)^6(0.40)^{10}) = 1.48\times10^{-41}$

(5 pts) What is the emf at 25ºC as read on the digital voltmeter?
$E = E^o - (RT/nF)\ln Q$
$= 0.18V-((8.3125\ Jmol\cdot K^{-1})(298.15\ K))/((30)(96485\ C\cdot mol^{-1}))\ln(1.48\times10^{-41})$
$=0.26$ V

(4 pts) What is the value of the equilibrium constant at 25ºC for the net spontaneous cell reaction?
$\ln K = nFE^o/RT$
$K = e^{nFE^o/RT} = e^{((30)(96485\ C\cdot mol\text{-}1)(0.18\ V))/((8.3145J\cdot mol\text{-}1\cdot K\text{-}1)(298.15K))} = 1.89\times10^{91}$

3) The following data was obtained experimentally at 25ºC

| [A] ($mol \cdot L^{-1}$) | [B] ($mol \cdot L^{-1}$) | [C] ($mol \cdot L^{-1}$) | Initial Rate ($mol \cdot L^{-1} \cdot s^{-1}$) |
|---|---|---|---|
| 0.0001 | 0.0200 | 0.0200 | $1.66\times10^{-7}$ |
| 0.0003 | 0.0200 | 0.0200 | $4.99\times10^{-7}$ |
| 0.0002 | 0.0100 | 0.0400 | $6.66\times10^{-7}$ |
| 0.0004 | 0.0300 | 0.0100 | $1.87\times10^{-7}$ |

(15 pts)What is the rate law?

$Rate=k[A]^x[B]^y[C]^z$

$\underline{1.66\times10^{-7} = k[0.0001]^x[0.0200]^y[0.0200]^z}$
$4.99\times10^{-7} = k[0.0003]^x[0.0200]^y[0.0200]^z$
$0.33 = (0.33)^x$

$\ln(0.33) = x\ln(0.33)$ $\quad x = 1.00$

$\underline{1.66\times10^{-7} = k[0.0001][0.0200]^y[0.0200]^z}$
$6.66\times10^{-7} = k[0.0002][0.0100]^y[0.0400]^z$

$0.25 = (0.50)(2.00)^y(0.50)^z$ $\quad 0.5 = (2.00)^y(0.50)^z$

$\ln(0.50) = y\ln(2.00) + z\ln(0.50)$

$y = (\ln(0.50) - z\ln(0.50))/\ln(2.00) = -1.00 + z$

$\underline{1.66\times10^{-7} = k[0.0001][0.0200]^y[0.0200]^z}$
$1.87\times10^{-7} = k[0.0004][0.0300]^y[0.0100]^z$

$0.89 = (0.25)(0.67)^y(2.00)^z$

$3.56= (0.67)^y(2.00)^z$

$\ln(3.56) = y\ln(0.67) + z\ln(2.00) = (-1.00 + z)\ln(0.67) + z\ln(2.00)$

$1.27 = 0.40 + 0.29z$ $\quad z = 3$

$y = -1.00 + z = -1.00 + 3$ $\quad y = 2$

$$Rate = k[A][B]^2[C]^3$$

(5 pts) What is the rate constant?

$1.66\times10^{-7} = k[0.0001][0.0200]^2[0.0200]^3$

$k = 5.2\times10^5\ L^5 \cdot mol^{-5} \cdot s^{-1}$

4) (15 pts) Balance the following equation:

$Zn(s) + NO_3^-(aq) \rightarrow Zn(OH)_4^{2-}(aq) + NH_3(s)$ (basic solution)

| | |
|---|---|
| $Zn \rightarrow Zn(OH)_4^{2-}$ | $NO_3^- \rightarrow NH_3$ |
| $Zn \rightarrow Zn(OH)_4^{2-}$ | $NO_3^- \rightarrow NH_3$ |
| $Zn + H_2O \rightarrow Zn(OH)_4^{2-}$ | $NO_3^- \rightarrow NH_3 + 3H_2O$ |
| $Zn + 4H_2O + 4OH^- \rightarrow Zn(OH)_4^{2-} + 4H_2O$ | $NO_3^- + 9H_2O \rightarrow NH_3 + 3H_2O + 9OH^-$ |
| $Zn + 4OH^- \rightarrow Zn(OH)_4^{2-} + 2e^-$ | $NO_3^- + 6H_2O + 8e^- \rightarrow NH_3 + 9OH^-$ |
| $4(Zn + 4OH^- \rightarrow Zn(OH)_4^{2-} + 2e^-)$ | $NO_3^- + 6H_2O + 8e^- \rightarrow NH_3 + 9OH^-$ |

$4Zn(s) + 7OH^-(aq) + NO_3^-(aq) + 6H_2O(l) \rightarrow 4Zn(OH)_4^{2-}(aq) + NH_3(s)$

6) (2 pts) Which of the following is true for a galvanic cell?

1. The electrons flow is from negative electrode to the positive electrode
2. the electrons flow is from the anode to the cathode
3. The electron flow is from oxidizing agent to the reduced agent

a. 1 only
b. 2 only
c. 3 only
d. 1 and 2 only (Answer)
e. 1, 2, and 3

(4 pts) What are two common differences between Galvanic cells and electrolytic cells?

| Galvanic | Electrolytic |
|---|---|
| 2 compartments | 1 compartment |
| 2 analytes | 1analyte |
| standard temp & press | non standard temp & press |
| No external power source | External power source |

6) Consider the reaction

$$3A+B+C \rightarrow D + E$$

Where the rate law is defined as

$$-\frac{\Delta A}{\Delta t} = k[A]^2[B][C]$$

An experiment is carried out where $[B]_o = [C]_o = 1.00\ mol\cdot L^{-1}$ and $[A]_o = 1.00\times10^{-4}\ mol\cdot L^{-1}$

(15 pts) After 3.00 minutes, $[A] = 3.26\times10^{-5}\ mol\cdot L^{-1}$.

What is the value of k in $L^3\cdot mol^{-3}\cdot s^{-1}$

$$-\frac{\Delta A}{\Delta t} = k[A]^2[B][C]$$

$$\frac{\Delta A}{[A]^2} = -k[B][C]\Delta t$$

$$\int_{[A]_o}^{[A]_t}\frac{1}{[A]^2}dA = -k[B][C]\int_0^t dt$$

$$-\frac{1}{[A]_t}+\frac{1}{[A]_o} = -k[B][C]t$$

$$k = \frac{1}{[B][C]t}\left(\frac{1}{[A]_t}-\frac{1}{[A]_o}\right)$$

$$k = \frac{1}{\left(1\frac{mol}{L}\right)\left(1\frac{mol}{L}\right)(3m)\left(\frac{60s}{1m}\right)}\left(\frac{1}{3.26\times10^{-5}\frac{mol}{L}}-\frac{1}{1.00\times10^{-4}\frac{mol}{L}}\right)$$

$$k = 1.15\times10^{2}\frac{L^3}{mol^3 s}$$

(8 pts) What is the half life for this experiment?

$$t = \frac{1}{[B][C]k}\left(\frac{1}{[A]_t}-\frac{1}{[A]_o}\right)$$

$$t = \frac{1}{\left(1\frac{mol}{L}\right)\left(1\frac{mol}{L}\right)\left(1.15\times10^{2}\frac{L^3}{mol^3 s}\right)}\left(\frac{1}{5.00\times10^{-5}\frac{mol}{L}}-\frac{1}{1.00\times10^{-4}\frac{mol}{L}}\right)$$

$$t = 87.0s$$

(5 pts) What is the concentration of C after 10.0 minutes?

The concentration of C is not effected by time therefore the concentration of C after 10 m will remain $1\ mol\cdot L^{-1}$

7) (10 pts) Write the cell diagram for the reaction

$2Cr^{3+}(aq) + H_2(g) \rightarrow + 2H^+(aq) + 2Cr^{2+}(aq)$

$Pt|H_2(g)|H^+(aq)||Cr^{3+}(aq),Cr^{2+}(aq)|Pt(s)$

8) Molten magnesium chloride is electrolyzed using inert electrodes and reactions represented by the following equations occur:

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

$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$

(3 pts) Concerning this electrolysis, which of the following statements is TRUE?

a) Oxidation occurs at the cathode.
b) $Mg^{2+}$ ions are reduced at the anode.
c) Electrons pass trough the metallic part of the circuit form $Mg^{2+}$ ions to the $Cl^-$ ions.
d) $Cl^-$ ions are oxidizing agents.
e) The cations in the electrolyte undergo reduction (Answer)

(8 pts) What current is required to produce 2 grams of Mg metal in 14 hours?

2 grams Mg × (1 mol Mg/ 24.31 g Mg) = 0.08 mol Mg

0.08 mol Mg × (2 mol e-/1 mol Mg) = .16 mol e-

14 h × (60 m / 1 h) ×(60 s / 1 m) = 50400 s

n = It/F rearrange I = nF/t = ((.16 mol e-)(96485 $C \cdot mol^{-1}$)/(50400 s)) = 0.31 A

(10 pts) What volume of $Cl_2(g)$ is produced if 2.00 A are passed through the solution for 4.00 hours at a pressure of 1 atm at 25ºC?

4 h × (60 m /1 h) ×(60 s / 1 m) = 14400 s

Q = I×t =(2.00 A)(14400 s) = 28800 C

n = Q/F = 28800 C / 96485 $C \cdot mol^{-1}$ = 0.29 mol of $e^-$

0.29 mol e- × (1 mol $Cl_2$/2 mol e-) = 0.15 mol e-

1 atm = 101325 Pa 25ºC = 298.15 K

PV=nRT rearrange V= nRT/P

V= ((.15 mol $e^-$)(8.3145 $J \cdot mol^{-1} \cdot K^{-1}$)( 298.15 K))/(101325 Pa) = $3.7 \times 10^{-3}$ $m^3$

9) The rate of formation of $NO_2$ in the reaction $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2$ is 5.78 (mol $NO_2$)$\cdot L^{-1} \cdot s^{-1}$

(3 pts) What is the unique average reaction rate?

¼(5.78) = 1.45 $mol \cdot L^{-1} \cdot s^{-1}$

(3 pts) What is the rate of formation of $O_2$?

¼(5.78) = 1.45 (mol $O_2$)$\cdot L^{-1} \cdot s^{-1}$

(3 pts) What is the rate of $N_2O_5$ decomposition?

½ (5.78) = 2.89 (mol $N_2O_5$) $\cdot L^{-1} \cdot s^{-1}$