

Chem. 6C Midterm 1

Version B

October 19, 2007

Name _____

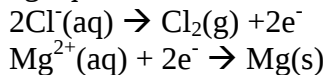
Student Number _____

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

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

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



- (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 through the metallic part of the circuit from 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?

$$2 \text{ grams Mg} \times (1 \text{ mol Mg} / 24.31 \text{ g Mg}) = 0.08 \text{ mol Mg}$$

$$0.08 \text{ mol Mg} \times (2 \text{ mol e}^- / 1 \text{ mol Mg}) = .16 \text{ mol e}^-$$

$$14 \text{ h} \times (60 \text{ min} / 1 \text{ h}) \times (60 \text{ s} / 1 \text{ min}) = 50400 \text{ s}$$

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

- (10 pts) What volume of $\text{Cl}_2(\text{g})$ is produced if 2.00 A are passed through the solution for 4.00 hours at a pressure of 1 atm at 25°C ?

$$4 \text{ h} \times (60 \text{ min} / 1 \text{ h}) \times (60 \text{ s} / 1 \text{ min}) = 14400 \text{ s}$$

$$Q = I \times t = (2.00 \text{ A})(14400 \text{ s}) = 28800 \text{ C}$$

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

$$0.29 \text{ mol e}^- \times (1 \text{ mol Cl}_2 / 2 \text{ mol e}^-) = 0.15 \text{ mol e}^-$$

$$1 \text{ atm} = 101325 \text{ Pa} \quad 25^\circ\text{C} = 298.15 \text{ K}$$

$$PV = nRT \text{ rearrange } V = nRT/P$$

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

- 2) The rate of formation of NO_2 in the reaction $2\text{N}_2\text{O}_5(\text{g}) \rightarrow 4\text{NO}_2(\text{g}) + \text{O}_2$ is $5.78 (\text{mol NO}_2) \cdot \text{L}^{-1} \cdot \text{s}^{-1}$

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

$$\frac{1}{4}(5.78) = 1.45 \text{ mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}$$

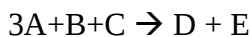
- (3 pts) What is the rate of formation of O_2 ?

$$\frac{1}{4}(5.78) = 1.45 (\text{mol O}_2) \cdot \text{L}^{-1} \cdot \text{s}^{-1}$$

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

$$\frac{1}{2}(5.78) = 2.89 (\text{mol N}_2\text{O}_5) \cdot \text{L}^{-1} \cdot \text{s}^{-1}$$

3) Consider the reaction



Where the rate law is defined as

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

An experiment is carried out where $[B]_0 = [C]_0 = 1.00 \text{ mol} \cdot \text{L}^{-1}$ and $[A]_0 = 1.00 \times 10^{-4} \text{ mol} \cdot \text{L}^{-1}$

(15 pts) After 3.00 minutes, $[A] = 3.26 \times 10^{-5} \text{ mol} \cdot \text{L}^{-1}$.

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

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

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

$$\int_{[A]_0}^{[A]_t} \frac{1}{[A]^2} dA = -k[B][C] \int_0^t dt$$

$$-\frac{1}{[A]_t} + \frac{1}{[A]_0} = -k[B][C]t$$

$$k = \frac{1}{[B][C]t} \left(\frac{1}{[A]_t} - \frac{1}{[A]_0} \right)$$

$$k = \frac{1}{\left(1 \frac{\text{mol}}{\text{L}}\right) \left(1 \frac{\text{mol}}{\text{L}}\right) (3\text{m}) \left(\frac{60\text{s}}{1\text{m}}\right)} \left(\frac{1}{3.26 \times 10^{-5} \frac{\text{mol}}{\text{L}}} - \frac{1}{1.00 \times 10^{-4} \frac{\text{mol}}{\text{L}}} \right)$$

$$k = 1.15 \times 10^2 \frac{\text{L}^3}{\text{mol}^3 \cdot \text{s}}$$

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

$$t = \frac{1}{[B][C]k} \left(\frac{1}{[A]_t} - \frac{1}{[A]_0} \right)$$

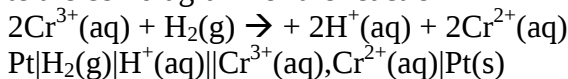
$$t = \frac{1}{\left(1 \frac{\text{mol}}{\text{L}}\right) \left(1 \frac{\text{mol}}{\text{L}}\right) \left(1.15 \times 10^2 \frac{\text{L}^3}{\text{mol}^3 \cdot \text{s}}\right)} \left(\frac{1}{5.00 \times 10^{-5} \frac{\text{mol}}{\text{L}}} - \frac{1}{1.00 \times 10^{-4} \frac{\text{mol}}{\text{L}}} \right)$$

$$t = 87.0\text{s}$$

(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 $1 \text{ mol} \cdot \text{L}^{-1}$

4) (10 pts) Write the cell diagram for the reaction



5) The following data was obtained experimentally at 25°C

[A] (mol·L ⁻¹)	[B] (mol·L ⁻¹)	[C] (mol·L ⁻¹)	Initial Rate (mol·L ⁻¹ ·s ⁻¹)
0.0001	0.0200	0.0200	1.66×10 ⁻⁷
0.0003	0.0200	0.0200	4.99×10 ⁻⁷
0.0002	0.0100	0.0400	6.66×10 ⁻⁷
0.0004	0.0300	0.0100	1.87×10 ⁻⁷

(15 pts) What is the rate law?

$$\text{Rate} = k[A]^x[B]^y[C]^z$$

$$\begin{aligned} \frac{1.66 \times 10^{-7}}{4.99 \times 10^{-7}} &= \frac{k[0.0001]^x[0.0200]^y[0.0200]^z}{k[0.0003]^x[0.0200]^y[0.0200]^z} \\ 0.33 &= (0.33)^x \end{aligned}$$

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

$$\begin{aligned} \frac{1.66 \times 10^{-7}}{6.66 \times 10^{-7}} &= \frac{k[0.0001][0.0200]^y[0.0200]^z}{k[0.0002][0.0100]^y[0.0400]^z} \\ 0.25 &= (0.50)(2.00)^y(0.50)^z \end{aligned}$$

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

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

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

$$\begin{aligned} \frac{1.66 \times 10^{-7}}{1.87 \times 10^{-7}} &= \frac{k[0.0001][0.0200]^y[0.0200]^z}{k[0.0004][0.0300]^y[0.0100]^z} \\ 0.89 &= (0.25)(0.67)^y(2.00)^z \end{aligned}$$

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

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

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

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

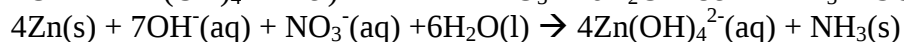
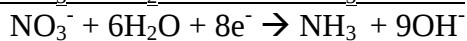
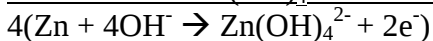
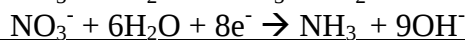
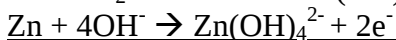
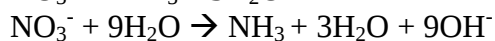
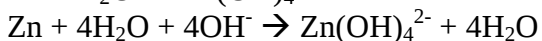
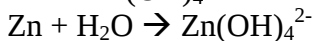
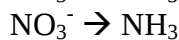
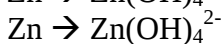
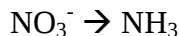
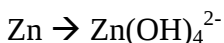
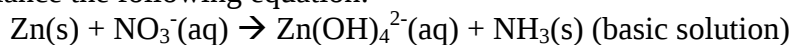
$$y = -1.00 + z = -1.00 + 3 \quad y = 2$$

$$\text{Rate} = k[A][B]^2[C]^3$$

(5 pts) What is the rate constant?

$$\begin{aligned} 1.66 \times 10^{-7} &= k[0.0001][0.0200]^2[0.0200]^3 \\ k &= 5.2 \times 10^5 \text{ L}^5 \cdot \text{mol}^{-5} \cdot \text{s}^{-1} \end{aligned}$$

6) (15 pts) Balance the following equation:



7) (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

8) Answer the questions below using the following data

<u>Half Reaction</u>	<u>E° (V)</u>
$\text{Ag}^{2+}(\text{aq}) + \text{e}^- \rightarrow \text{Ag}^+(\text{aq})$	1.99
$\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Au}(\text{s})$	1.50
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	0.77
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	-0.126
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	-0.23
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al}(\text{s})$	-1.66
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ca}(\text{s})$	-2.76

(3 pts) Which is the strongest reducing agent? $\text{Ca}(\text{s})$

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

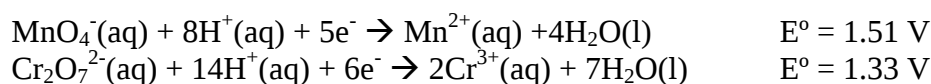
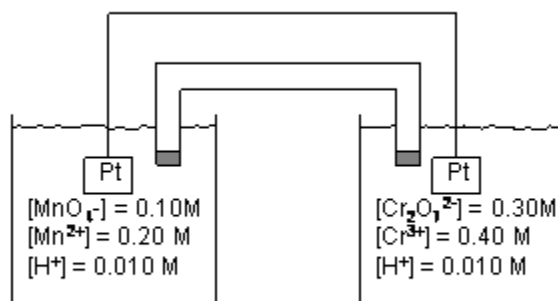
(3 pts) Will $\text{Al}(\text{s})$ dissolve in $1 \text{ mol} \cdot \text{L}^{-1} \text{HCl}$? Yes

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

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

At equilibrium the emf = 0 V

9) Answer the following questions using the given galvanic cell



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

(2 pts) What is the value of E°_{cell} ?
 $1.51 \text{ V} - 1.33 \text{ V} = 0.18 \text{ V}$

(3 pts) What is the oxidation state of Cr in $\text{Cr}_2\text{O}_7^{2-}$?
 $6+$

(5 pts) What is the balanced equation of this cell?
 $6(\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l}))$
 $5(2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) \rightarrow \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^-)$
 $6\text{MnO}_4^-(\text{aq}) + 10\text{Cr}^{3+}(\text{aq}) + 11\text{H}_2\text{O}(\text{l}) \rightarrow 6\text{Mn}^{2+}(\text{aq}) + 5\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 22\text{H}^+(\text{aq})$

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

$$\begin{aligned} Q &= \frac{[\text{Mn}^{2+}]^6 [\text{Cr}_2\text{O}_7^{2-}]^5 [\text{H}^+]^{22}}{[\text{MnO}_4^-]^6 [\text{Cr}^{3+}]^{10}} \\ &= \frac{((0.20)^6 (0.30)^5 (0.010)^{22})}{((0.10)^6 (0.40)^{10})} = 1.48 \times 10^{-41} \end{aligned}$$

(5 pts) What is the emf at 25°C as read on the digital voltmeter?
 $E = E^\circ - (RT/nF)\ln Q$
 $= 0.18\text{V} - ((8.3125 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})(298.15 \text{ K})/((30)(96485 \text{ C}\cdot\text{mol}^{-1}))\ln(1.48 \times 10^{-41}))$
 $= 0.26 \text{ V}$

(4 pts) What is the value of the equilibrium constant at 25°C for the net spontaneous cell reaction?

$$\begin{aligned} \ln K &= nFE^\circ/RT \\ K &= e^{nFE^\circ/RT} = e^{((30)(96485 \text{ C}\cdot\text{mol}^{-1})(0.18 \text{ V})/((8.3145 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})(298.15 \text{ K}))} = 1.89 \times 10^{91} \end{aligned}$$