

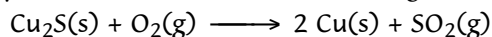
**QUIZ FIVE**  
**CHM 205 (DR. MATTSON)**  
**31 MARCH 2004**

**Quiz: \_\_\_\_\_ / 50**  
A  $\geq$  46.5; B+  $\geq$  43.5; B  $\geq$  41.0;  
C+  $\geq$  37.5; C  $\geq$  34.00; D  $\geq$  30.00

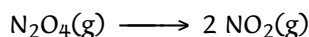
**Name:**

**Instructions:** Show all work whenever a calculation is required! You will receive credit for how you worked each problem as well as for the correct answer. This exam is worth 50 points. Scores greater than 50 will be recorded as 50. **BOX YOUR ANSWERS!**

1. (2 pts) Calculate  $\Delta S^\circ$  for the following reaction.



2. Nitrogen dioxide is a red gas while  $\text{N}_2\text{O}_4$  is colorless.  $\text{N}_2\text{O}_4$  can be thought of as two  $\text{NO}_2$  molecules joined by a nitrogen-nitrogen bond. At low temperatures, the mixture is colorless, but as the temperature is increased, the red color of the mixture increases.



- (i) (3 pts) What can you conclude about the signs of  $\Delta H^\circ$ ,  $\Delta S^\circ$ , and  $\Delta G^\circ$ , respectively? Circle choice.

$\Delta H^\circ$  is  $> 0$  or  $= 0$  or  $< 0$

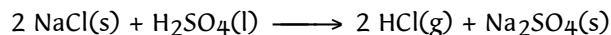
$\Delta S^\circ$  is  $> 0$  or  $= 0$  or  $< 0$

$\Delta G^\circ$  is  $> 0$  or  $= 0$  or  $< 0$

- (ii) (1 pt) This reaction is:

- A. spontaneous at all temperatures.
- B. non-spontaneous at all temperatures.
- C. spontaneous at high temperatures only.
- D. spontaneous at low temperatures only.

3. Gaseous HCl is produced by reacting sulfuric acid with NaCl:



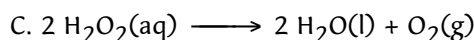
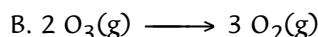
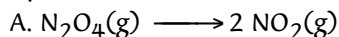
$$\Delta H^\circ = +71 \text{ kJ} \quad \Delta S^\circ = +222 \text{ J/K}$$

- a. (2 pts) Calculate  $\Delta G^\circ$  for this reaction.

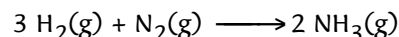
- b. (1 pt) Is the reaction spontaneous at 298 K?

4. (3 pts) Calculate the equilibrium constant,  $K_p$  at 25  $^\circ\text{C}$  for the reaction in the previous question.

5. (3 pts) Which of these is/are entropy-favored?



6. (2 pts) Consider the formation of ammonia:



Under what conditions of temperature is this reaction spontaneous?

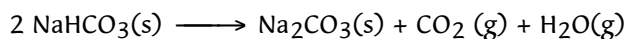
- A. high temperatures only
- B. low temperatures only
- C. all temperatures
- D. never spontaneous

Calculations and/or explanation.

7. (5 pts) Ammonia production (previous problem) is kinetically very slow. What might be done to increase the rate of ammonia production (See previous question)? Circle all that would help achieve this goal.

- A. Run the reaction at very low temperatures.
- B. Run the reaction at low pressures
- C. Run the reaction at as high temperature as possible, maintaining  $\Delta G < 0$ .
- D. Run the reaction at high pressures.
- E. Use a catalyst if possible.

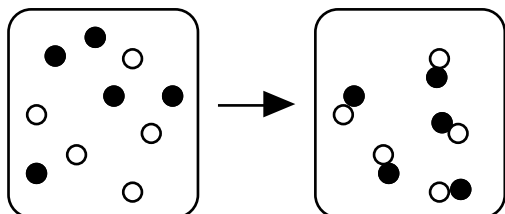
8. (3 pts) Sodium carbonate can be made by heating sodium bicarbonate:



$$\Delta H^\circ = +136 \text{ kJ} \quad \Delta G^\circ = +35 \text{ kJ at } 25^\circ \text{C.}$$

At what temperature, if any, does this reaction become spontaneous?

9. (3 pts) The reaction shown below is spontaneous at 25 °C. Predict the signs of  $\Delta H^\circ$ ,  $\Delta G^\circ$ , and  $\Delta S^\circ$

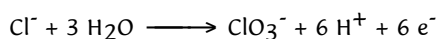
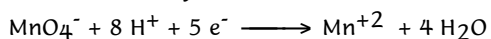


$$\Delta H^\circ > 0 \text{ or } = 0 \text{ or } < 0$$

$$\Delta G^\circ > 0 \text{ or } = 0 \text{ or } < 0$$

$$\Delta S^\circ > 0 \text{ or } = 0 \text{ or } < 0$$

10. (2 pts) If you were to balance the following two half reactions, how many electrons would be transferred in the balanced equation? (You do not need to actually balance it.)



11. (a) (1 pt) Will Zn(s) reduce  $\text{Pb}^{2+}$  to Pb(s) as a spontaneous reaction? (b) (2 pts) Write the balanced equation and (c) (2 pts) Calculate  $E^\circ_{\text{rxn}}$ .

(a)
(b)
(c)

12. (a) (2 pts) Determine  $E^\circ$  for the reaction:



(b) (3 pts) Calculate E for the reaction.

(a)
(b)

13. (3 pts) Determine the equilibrium constant,  $K_c$  for the following galvanic cell.



14. (3 pts) Determine  $\Delta G^\circ$  for the reaction in the previous problem

15. (3 pts) Chromium is plated from  $\text{Cr}^{+6}$  in an electrolytic cell. What mass of chromium can be plated by a current of 5.0 amps operating for 1.50 hour?

### Thermodynamic Values:

Substance	$\Delta H^\circ_f$ (kJ/mol)	$\Delta G^\circ_f$ (kJ/mol)	$S^\circ$ (J/mol K)
C(s) graphite	0	0	6
CO <sub>2</sub> (g)	-393.5	-394	214
Cu <sub>2</sub> S(s)	-80	-86	121
Cu(s)	0	0	33
H <sub>2</sub> (g)	0	0	131
H <sub>2</sub> O(l)	-286	-237	70
H <sub>2</sub> O(g)	-242	-229	189
Fe(s)	0	0	27
Fe <sub>2</sub> O <sub>3</sub> (s)	-826	-740	90
H <sub>2</sub> (g)	0	0	131
N <sub>2</sub> (g)	0	0	191
NH <sub>3</sub> (g)	-46	-17	192
O <sub>2</sub> (g)	0	0	205
SO <sub>2</sub> (g)	-297	-300	248

	$E^\circ$ (V)
$\text{Ag}^+ + e^- \longrightarrow \text{Ag}$	+0.80
$\text{Fe}^{3+} + e^- \longrightarrow \text{Fe}^{2+}$	+0.77
$\text{I}_2(\text{s}) + 2 e^- \longrightarrow 2 \text{I}^-$	+0.54
$\text{Cu}^{2+} + 2 e^- \longrightarrow \text{Cu}$	+0.34
$\text{Pb}^{2+} + 2 e^- \longrightarrow \text{Pb}$	-0.13
$\text{Ni}^{2+} + 2 e^- \longrightarrow \text{Ni}$	-0.26
$\text{Fe}^{2+} + 2 e^- \longrightarrow \text{Fe}$	-0.44
$\text{Cr}^{3+} + 3 e^- \longrightarrow \text{Cr}$	-0.73
$\text{Zn}^{2+} + 2 e^- \longrightarrow \text{Zn}$	-0.76
$\text{Mg}^{2+} + 2 e^- \longrightarrow \text{Mg}$	-1.66

### Useful equations

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

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

$$\Delta G^\circ = -RT\ln K$$

$$\Delta G^\circ = -nFE^\circ$$

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

$$R = 8.314 \text{ J/mol K} = 0.0821 \text{ L atm/mol K}$$

$$E = E^\circ - \frac{0.059}{n} \log Q$$

$$\text{Charge(coulombs)} = \text{Current(amps)} \times \text{Time(s)}$$

$$F = 96500 \text{ J/mol } e^- \text{ V}$$

$$F = 1 \text{ mol } e^- = 96,500 \text{ coul}$$

Answers:

1.  $-12 \text{ J/K}$

2.

(i)

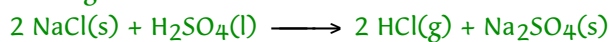
$$\Delta H^\circ > 0$$

$$\Delta S^\circ > 0$$

$$\Delta G^\circ < 0$$

(ii) C

3. Gaseous HCl is produced by reacting sulfuric acid with NaCl:



$$\Delta H^\circ = +71 \text{ kJ} \quad \Delta S^\circ = +222 \text{ J/K}$$

a.  $\Delta G^\circ = 4.8 \text{ kJ}$

b. No

4.  $K_p = 0.142$

5. A, B and C

6. B

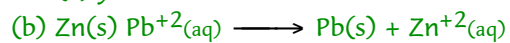
7. C, D, and E

8.  $T = 401 \text{ K}$

9.  $\Delta G^\circ < 0$  and  $\Delta S^\circ < 0$  therefore,  $\Delta H^\circ < 0$

10.  $30 e^-$

11. (a) yes



(c)  $E^\circ_{\text{rxn}} = +0.63 \text{ v}$

12. (a)  $E^\circ = 1.56 \text{ v}$

(b)  $E = 1.45 \text{ v}$

13.  $K_c = 2.5 \times 10^{+4}$

14.  $\Delta G^\circ = -25 \text{ kJ}$

15.  $2.42 \text{ g}$