Chemistry 162B  Final Exam  A
Name____________________
June 8, 2000
TA____________________

I have neither given nor received any information on this exam

__________________________________  __/___/___
sign  date

O.K. so here is the final exam. MAKE SURE YOU INDICATE WHICH EXAM YOU HAVE (A or B). This is all multiple choice so there is NO partial credit. YOU CAN ALL DO THIS! Calm down, relax and think calmly and clearly about the chemistry involved. Frantic searching for the right equation without thinking about why will not help. Remember your units, they will help. Good luck and have a great summer.

Some potentially useful constants: F=9.65x10^4 C/mol, R=8.315 J/(mol K) or .0821 (L atm)/(mol K), c=2.998x10^8 m/s, h=6.626x10^{-34} J s, π=3.14159, e = 2.7183 K_w=1x10^{-14}.

**Part I** (Non calculation or minor calculation multiple choice. Use space provided or the page backsides to work problems)

Questions 1 and 2 are based on the potential energy surface:

![](ReactionCoordinateDiagram.png)

A-1) Is the reaction A_2+B_2 -> 2AB endothermic or exothermic? (2)
(A) endothermic  (B) exothermic.
A-2) If a solid line represents a complete bond and a dashed line represents a bond which is forming or breaking, which of the following best describes the transition state? (2)

(A)  

(B)  

(C)  

(D)  

A-3) What is the oxidation state of the Ni in \([\text{Ni(CN)}_4]^{-2}\)? (2)

(A) +4  (B) -2  (C) +2  (D) +6

Given the following reaction data:

<table>
<thead>
<tr>
<th>Run</th>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Initial rate (M/s)</th>
<th>Temp. (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0012</td>
<td>0.0018</td>
<td>7.8\times10^{-6}</td>
<td>298</td>
</tr>
<tr>
<td>2</td>
<td>0.0012</td>
<td>0.0036</td>
<td>3.1\times10^{-5}</td>
<td>298</td>
</tr>
<tr>
<td>3</td>
<td>0.0024</td>
<td>0.0018</td>
<td>1.6\times10^{-5}</td>
<td>298</td>
</tr>
</tbody>
</table>

A-4) What is the rate law of the reaction \(2A + B_2 \rightarrow 2AB\)? (4)

(A) \(\text{rate}=k[A]^2[B_2]\)  
(B) \(\text{rate}=k[A][B_2]^2\)  
(C) \(\text{rate}=k[A][B_2]\)  
(D) \(\text{rate}=k[A]^2[B_2]^2\)

A-5) The molecule A decays in a second order process with a half life of 3 years. If you start with 5.5M A, what is the rate constant, \(k\)? (4)

(A) 0.061 L/(mol\ year)  
(B) .231 year\(^{-1}\)  
(C) .030 L/(mol\ year)  
(D) 3 year
A-6) Consider the atomic radii of ruthenium (Ru) and osmium (Os). Which of the following is true of the size difference? (2)
(A) Ru>Os  (B) Os>Ru  (C) Ru=Os  (D) there is not enough data to tell.

A-7) The reaction \( \text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g) \) occurs in two steps:

1. \( \text{NO}_2(g) + \text{NO}_2(g) \rightarrow \text{NO}_3(g) + \text{NO}(g) \) (slow)
2. \( \text{NO}_3(g) + \text{CO}(g) \rightarrow \text{NO}_2(g) + \text{CO}_2(g) \) (fast)

What is the rate law for the overall reaction \( \text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g) \)? (4)
(A) rate=\( k[\text{NO}_3][\text{CO}] \)  (B) rate=\( k[\text{NO}_2][\text{CO}] \)  (C) rate=\( k[\text{NO}_2]^2 \)  (D) rate=\( k[\text{NO}_2]^2[\text{CO}]/[\text{NO}] \)

A-8) Given the following elementary reactions:

1. \( \text{P}_4(s) + 6\text{Cl}_2(g) \rightarrow 4\text{PCl}_3(g) \)
2. \( 4\text{PCl}_3(g) + 4\text{Cl}_2(g) \rightarrow 4\text{PCl}_5(g) \)

Which of the following is the correct reaction quotient for the overall reaction? (3)
(A) \( [\text{PCl}_3]^4/[\text{Cl}_2]^6 \)  (B) \( [\text{PCl}_3]^4/[\text{Cl}_2]^4[\text{PCl}_3]^4 \)
(C) \( [\text{PCl}_3]^4/[\text{Cl}_2]^6 + \text{PCl}_5]^4/[\text{Cl}_2]^4[\text{PCl}_3]^4 \)  (D) \( [\text{PCl}_3]^4/[\text{Cl}_2]^{10} \)

A-9) Which of the following salts form basic solutions in water? (4)
(A) \( \text{NH}_4\text{CN} \)  (B) \( \text{FeF}_3(s) \)  (C) \( \text{NaNO}_3 \)  (D) \( \text{NH}_4\text{Cl} \)

A-10) In forming the complex ion \([\text{ML}_6]^{n+}\) the metal ion (\( \text{M}^{n+} \)) is: (2)
(A) a Lewis acid  (B) a proton acceptor  (C) a Lewis base  (D) a proton donor
A-11) Based only on the following $K_{sp}$ data: $\text{MgSO}_4(s) = 5.9 \times 10^{-3}$, $\text{PbCl}_2(s) = 1.7 \times 10^{-5}$

(A) MgSO$_4$(s) is more soluble than PbCl$_2$(s)
(B) PbCl$_2$(s) is more soluble than MgSO$_4$(s)
(C) MgSO$_4$(s) and PbCl$_2$(s) are equally soluble.
(D) You cannot compare the $K_{sp}$ values of MgSO$_4$(s) and PbCl$_2$(s)

A-12) Which of the following statements about $d$ orbitals is false? (2)

(A) They can be involved in $\delta$ bonds.
(B) you can have $nd$ orbitals for any principle quantum number $n$.
(C) There are 5 $d$ orbitals.
(D) the $nd$ orbitals are lower in energy than the $ns$ orbitals.

A-13) If a redox reaction has a large value of $E^0_{\text{cell}}$ (2)

(A) $K$ is large and $\Delta G_{\text{rxn}}$ is small (more negative).
(B) $K$ is small and $\Delta G_{\text{rxn}}$ is large (more positive).
(C) $K$ is large and $\Delta G_{\text{rxn}}$ is large (more positive).
(D) $K$ is small and $\Delta G_{\text{rxn}}$ is small (more negative).
A-14) Which of the following is a linkage isomer of

\[
\begin{array}{ccc}
\text{C} & \text{M} & \text{D} \\
\text{A} & \text{D} & \text{A} \\
\text{C} & \text{B} & \text{B} \\
\text{Cl}_2 & & \\
\end{array}
\]

? (2)

(A)

\[
\begin{array}{ccc}
\text{C} & \text{M} & \text{D} \\
\text{D} & \text{A} & \text{B} \\
\text{C} & \text{B} & \text{B} \\
\text{Cl}_2 & & \\
\end{array}
\]

(B)

\[
\begin{array}{ccc}
\text{C} & \text{M} & \text{D} \\
\text{A} & \text{B} & \text{D} \\
\text{C} & \text{B} & \text{B} \\
\text{Cl}_2 & & \\
\end{array}
\]

(C)

\[
\begin{array}{ccc}
\text{C} & \text{M} & \text{D} \\
\text{A} & \text{B} & \text{D} \\
\text{C} & \text{C} & \text{C} \\
\text{Cl}_2 & & \\
\end{array}
\]

(D)
A-15) If the electrochemical cell \( \text{Zn(s)} | \text{Zn}^{2+} || \text{Cu}^{2+} | \text{Cu(s)} \) with \( E_{\text{cell}}^0 = +1.10 \text{V} \) is at equilibrium and a voltage of 0.8V is applied what will happen when the reaction stops? (4)

(A) The applied voltage is below \( E_{\text{cell}}^0 \) so the reaction will not start to begin with.

(B) You will have a voltaic cell where the concentrations of electrolyte solutions will be equal.

(C) You will have a voltaic cell where the concentration of the electrolyte on the cathode side is greater than the concentration of the electrolyte on the anode side.

(D) You will have a voltaic cell where the concentration of the electrolyte on the anode side is greater than the concentration of the electrolyte on the cathode side.

A-16) The chlorophyll molecule contains \( \text{Mg}^{2+} \) surrounded by a large organic complex. The \( \text{Mg}^{2+} \) center looks something like this:

![Mg2+ structure]

Which of the following best describes the organic complex? (2)

(A) Bidentate ligand

(B) Unidentate ligand

(C) Polydentate ligand

(D) Four separate ligands.
A-17) What is the coordination number in \( \text{M} \)?

(A) 6 \hspace{1cm} (B) 8 \hspace{1cm} (C) 15 \hspace{1cm} (D) 2

A-18) What is the electronic configuration of silver (Ag atomic number 47)?

(A) \( 5s^2 4d^9 \) \hspace{1cm} (B) \( 5s^0 4d^{10} 5p^1 \) \hspace{1cm} (C) \( 5s^1 4d^{10} \) \hspace{1cm} (D) \( 5s^1 5d^{10} \)

### Part II

(Problems. Use space provided or the page backsides to work problems)

Questions 19-21 are together

A-19) What is \( \Delta G^0_{\text{rxn}} \) for the reaction \( \text{Cu}_2\text{S(s)} \rightarrow 2\text{Cu(s)} + \text{S(s)} \)?

(A) \(-86.2 \text{ kJ/mol}\) \hspace{1cm} (B) \(+86.2 \text{ kJ/mol}\) \hspace{1cm} (C) \(-79.5 \text{ kJ/mol}\) \hspace{1cm} (D) \(+79.5 \text{ kJ/mol}\)

A-20) What is \( \Delta G^0_{\text{rxn}} \) for the reaction \( \text{S(s)} + \text{O}_2(g) \rightarrow \text{SO}_2(g) \)?

(A) \(-296.8 \text{ kJ/mol}\) \hspace{1cm} (B) \(+296.8 \text{ kJ/mol}\) \hspace{1cm} (C) \(-300.2 \text{ kJ/mol}\) \hspace{1cm} (D) \(+300.2 \text{ kJ/mol}\)

A-21) Is the reaction \( \text{Cu}_2\text{S(s)} + \text{O}_2(g) \rightarrow 2\text{Cu(s)} + \text{SO}_2(g) \) spontaneous?

(A) yes \hspace{1cm} (B) no \hspace{1cm} (C) (there is not enough information to tell.)
Questions 22-26 concern the titration of formic acid (HCOOH) with the strong base NaOH.

A-22) If you add 10.0 ml of 0.150M formic acid (HCOOH) to 40.0 ml H₂O, what is the pH? (5)
   (A) 5.27      (B) 2.63      (C) 2.28      (D) 7.00

A-23) When titrating the formic acid with 0.100M NaOH, how many ml must be added to reach the midpoint (the point where [HCOOH] = [HCOO⁻]; the point where buffer capacity is greatest)? (8)
   (A) 15.0 ml   (B) 37.5 ml   (C) 7.50 ml   (D) 10.0 ml

A-24) How many ml (total) of NaOH must be added to reach the equivalence point? (8)
   (A) 15.0 ml   (B) 37.5 ml   (C) 7.50 ml   (D) 10.0 ml
A-25) What is the pH at the equivalence point? (6)

(A) 5.95  (B) 8.05  (C) 2.63  (D) 5.04

A-26) Which of the following titration curves best represents your system? (4)

(A)  

(B)  

(C)  

(D)
For questions 27-30 you have a saturated solution of copper nitrate ($\text{Cu(NO}_3\text{)}_2$) and you wish to extract 1g of solid copper by applying an electric current.

A-27) How many moles of copper are in one gram of solid copper? (4)
   (A) 1.0 mol  (B) 63.6 mol  (C) 0.0157 mol  (D) 0.0315 mol

A-28) What is the corresponding moles of electrons in this electrolysis? (4)
   (A) 1.0 mol  (B) 63.5 mol  (C) 0.0157 mol  (D) 0.0314 mol

A-29) What is the corresponding charge? (6)
   (A) $9.65\times10^4 \text{C}$  (B) $3.03\times10^3 \text{C}$  (C) $1.51\times10^3 \text{C}$  (D) $0.0315\times10^3 \text{C}$

A-30) If you wish to extract the solid copper in 5 minutes, what is the current needed? (6)
   (A) 10.1 A  (B) 5.00 A  (C) 321 A  (D) 608 A
Questions 31 and 32 are together

A-31) What is the pH of a saturated solution of magnesium carbonate (MgCO₃)? (6)

(A) 3.70  (B) 10.30  (C) 7.00  (D) 8.96

A-32) What is the new pH if you add 100ml of 0.001M HCl and then dilute the solution to a total volume of 1 L? (8)

(A) 10.27  (B) 3.60  (C) 7.00  (D) 3.73
Questions 33-34 deal with the electrolysis of a solution of barium chloride (BaCl$_2$)

A-33) What is produced at the anode? (6)
(A) Ba(s)  (B) Cl$_2$(g)  (C) H$_2$(g)  (D) O$_2$(g)

A-34) What is produced at the cathode? (6)
(A) Ba(s)  (B) Cl$_2$(g)  (C) H$_2$(g)  (D) O$_2$(g)

For questions 35-39, consider the following rate data for the reaction

\[ 2\text{NO}(g) + \text{Br}_2(g) \rightarrow 2\text{NOBr}(g) \]

<table>
<thead>
<tr>
<th>Run</th>
<th>[NO] (M)</th>
<th>[Br$_2$] (M)</th>
<th>Initial rate (M/s)</th>
<th>Temp. (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
<td>2.17x10$^{-5}$</td>
<td>298</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
<td>7.90x10$^{-5}$</td>
<td>400</td>
</tr>
</tbody>
</table>

If the rate law was determined to be rate=$k[\text{NO}]^2[\text{Br}_2]$.

A-35) What are the rate constants for reactions 1 and 2 ($k_1$,$k_2$)? (3)
(A) 2.17x10$^{-5}$, 7.90x10$^{-5}$  
(B) 4.34x10$^{-5}$, 7.90x10$^{-5}$  
(C) 4.34x10$^{-5}$, 1.58x10$^{-4}$  
(D) 2.17x10$^{-5}$, 1.58x10$^{-4}$
A-36) What is the activation energy, $E_a$? (5)

(A) 12.6 kJ/mol  (B) 50 kJ/mol  (C) 123 kJ/mol  (D) .123 kJ/mol

A-37) What fraction of molecular collisions will have enough energy to react at 500K? (8)

(A) 20.7  (B) 0.997  (C) 0.0483  (D) 0.736

A-38) What fraction of molecular collisions will have enough energy to react at 700K? (8)

(A) 0.998  (B) 0.115  (C) 0.083  (D) 8.71

A-39) How much faster or slower will the reaction be at 700K? (6)

(A) 2.38 times slower  (B) 1.4 times faster

(C) 2.38 times faster  (D) 1.4 times slower
For questions 40-44, at 1000K the reaction $3\text{H}_2(g) + \text{N}_2(g) \leftrightarrow 2\text{NH}_3(g)$ has an equilibrium constant $K_p$ of $3.56 \times 10^{-7} \text{ atm}^2$.

A-40) What is $K_c$ at 1000 K? (5)
(A) $24.6 \text{ M}^{-2}$  
(B) $2.40 \times 10^{-3} \text{ M}^{-2}$  
(C) $4.06 \times 10^{-2} \text{ M}^{-2}$  
(D) $5.28 \times 10^{-11} \text{ M}^{-2}$

A-41) If you start with 5.00 moles of $\text{N}_2(g)$, 3.00 moles of $\text{H}_2(g)$ and 1 mole $\text{NH}_3(g)$ in a 30.0 L container at 1000K, what is $Q_c$? (5)
(A) $2.38 \times 10^{-2} \text{ M}^{-2}$  
(B) $1.99 \text{ M}^{-2}$  
(C) $15.1 \text{ M}^{-2}$  
(D) $6.64 \times 10^{-2} \text{ M}^{-2}$

A-42) In which direction will this reaction proceed under the given conditions? (3)
(A) to the left  
(B) to the right  
(C) the reaction is already at equilibrium
A-43) What volume does the container need to be in order for the reaction to be at equilibrium with the given number of moles of reactants and products? (10)

(A) 0.342L  (B) 0.0302L  (C) 237L  (D) 0.569L

A-44) Given that $\Delta H_{\text{rxn}}^o = -91.8 \text{ kJ/mol}$, at what temperature will the reaction with the original moles of reactants and products be at equilibrium in a 30L container? (10)

(A) 769 K  (B) 1430 K  (C) 3.34 K  (D) 253 K
### Thermodynamic values at 298 K

<table>
<thead>
<tr>
<th>Formula</th>
<th>$\Delta H^0$kJ/mol</th>
<th>$\Delta G^0$kJ/mol</th>
<th>$S^0$J/(mol*K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Cu}_2\text{S(s)}$</td>
<td>-79.5</td>
<td>-86.2</td>
<td>120.9</td>
</tr>
<tr>
<td>$\text{Cu(s)}$</td>
<td>0</td>
<td>0</td>
<td>33.1</td>
</tr>
<tr>
<td>$\text{SO}_2(g)$</td>
<td>-296.8</td>
<td>-300.2</td>
<td>248.1</td>
</tr>
<tr>
<td>$\text{S(s)}$</td>
<td>0</td>
<td>0</td>
<td>31.9</td>
</tr>
<tr>
<td>$\text{O}_2(g)$</td>
<td>0</td>
<td>0</td>
<td>205.0</td>
</tr>
</tbody>
</table>

### Standard Electrode (Half-Cell) Potentials at 298 K

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$E^0$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Cl}_2(g) + 2\text{e}^- \leftrightarrow \text{Cl}^-(aq)$</td>
<td>+1.36</td>
</tr>
<tr>
<td>$\text{Cu}^{2+}(aq) + 2\text{e}^- \leftrightarrow \text{Cu(s)}$</td>
<td>+0.34</td>
</tr>
<tr>
<td>$\text{Pb}^{2+}(aq) + 2\text{e}^- \leftrightarrow \text{Pb(s)}$</td>
<td>-0.13</td>
</tr>
<tr>
<td>$\text{Zn}^{2+}(aq) + 2\text{e}^- \leftrightarrow \text{Zn(s)}$</td>
<td>-0.76</td>
</tr>
<tr>
<td>$\text{Ba}^{2+}(aq) + 3\text{e}^- \leftrightarrow \text{Ba(s)}$</td>
<td>-2.90</td>
</tr>
<tr>
<td>$2\text{H}_2\text{O}(l) + 2\text{e}^- \leftrightarrow \text{H}_2(g) + \text{OH}^-(aq)$</td>
<td>-0.42*</td>
</tr>
<tr>
<td>$2\text{H}_2\text{O}(l) \leftrightarrow \text{O}_2(g) + 4\text{H}^+ + 4\text{e}^-$</td>
<td>-0.82*</td>
</tr>
</tbody>
</table>

*At [H$^+$] and [OH$^-$] in distilled water

### Acid Dissociation Constants at 25°C

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>$K_{a1}$(M)</th>
<th>$K_{b1}$(M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (III)</td>
<td>$\text{Fe}^{3+}$</td>
<td>$6.8 \times 10^{-4}$</td>
<td></td>
</tr>
<tr>
<td>Hydrofluoric</td>
<td>HF</td>
<td>$6.8 \times 10^{-4}$</td>
<td></td>
</tr>
<tr>
<td>Carbonic</td>
<td>$\text{H}_2\text{CO}_3$</td>
<td>$4.3 \times 10^{-7}$</td>
<td></td>
</tr>
<tr>
<td>Formic</td>
<td>$\text{HCHO}_2$</td>
<td>$1.8 \times 10^{-4}$</td>
<td></td>
</tr>
<tr>
<td>Hydrocyanic</td>
<td>HCN</td>
<td>$4.9 \times 10^{-10}$</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>$\text{NH}_3$</td>
<td>$1.76 \times 10^{-5}$</td>
<td></td>
</tr>
</tbody>
</table>

$K_{sp} \text{ZnCO}_3 = 1.0 \times 10^{-10}$