1. Circle the complex or complex ion that should exhibit tetragonal Jahn Teller distortion. (1 pt)

\[ \text{[VCl}_4\text{]}^{2-} \quad \text{[VCl}_6\text{]}^{3-} \quad \text{[Co(NH}_3\text{)}_6\text{]}^{3+} \quad \text{Cr(CO)}_6 \]

2. Mark each of the following complexes as either square planar (D\(_{4h}\)) or tetrahedral (Td) (3 pts)

\[ \text{[CdBr}_4\text{]}^{2-} \quad \text{Ni(CO)}_4 \quad \text{[Co(CN)}_4\text{]}^{2-} \]

3. Consider a square planar, ML\(_4\) complex. (a) Construct a diagram of the relative energies of the valence d orbitals of the metal ion in a D\(_{4h}\) ligand field. Label all orbitals. (2 pts)

(c) Give the d orbital splitting diagram for a tetrahedral ML\(_4\) complex and state two factors that could favor Td ML\(_4\) over square planar ML\(_4\). (2 pts)
4. Give the steps in an efficient synthesis of the complex trans-[PtCl₂(NH₃)₂PPh₃]. You have available NaCl, NH₃, PPh₃ and K₂PtCl₄ to use in the synthesis. (2 pts)

5. Complete the following equations with the correct product(s) or write NR if no reaction is expected. (You need not balance any equations.) (3 pts)

(a) [Co(NH₃)₆]Cl₃ + 3 en ->
   en = 1,2-diaminoethane

(b) TaCl₄(PPh₃)CH₂CH₂CH₃ →(warm)->

(c) Fe(CO)₅ →(UV) →

6. The rate constant for exchange of H₂O with a [M(H₂O)₆]₃⁺ complex is over 10¹² times LARGER when M = Cr²⁺ than when M = Cr³⁺. The charge on M cannot be the sole factor controlling the rates since, for vanadium, the rate of H₂O exchange of [V(H₂O)₆]³⁺ is nearly 30 times greater than that of [V(H₂O)₆]²⁺. Explain as specifically as you can, why the rate of H₂O exchange is (M =) Cr²⁺ >> Cr³⁺ but (M =) V³⁺ > V²⁺. The information below may be useful to you. (4 pts)

Crystal Field Stabilization Energy (Dq) for Dissociative and Associative Transition States

<table>
<thead>
<tr>
<th>dⁿ, n=</th>
<th>Oₘ</th>
<th>C₄ᵥ</th>
<th>D₅h</th>
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<tbody>
<tr>
<td>1</td>
<td>4.00</td>
<td>4.57</td>
<td>5.28</td>
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<td>18.30</td>
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<tr>
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</tr>
<tr>
<td>6 LS</td>
<td>24.00</td>
<td>20.00</td>
<td>15.48</td>
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</table>
7. a) What is the formula of the most stable homoleptic carbonyl compound of cobalt? (1 pt)

b) Sketch and describe the molecular geometry of the cobalt carbonyl from part a. (1 pts)

c) If cobalt formed a carbonylate, what formula would you expect for the most stable anion? (1 pts)

8. Please identify the most likely product for each of the following reactions. Write NR if no reaction occurs.

   (a) $\eta^1$-(C${}_3$H${}_2$)Mn(CO)$_3$ $\rightarrow$ (UV) $\rightarrow$ (3 pts)

   (b) [PtCl$_4$]$^-$ + 2PPh$_3$ $\rightarrow$ (b)

   (c) Ni$^{2+}$(aq) + excess I$^-$ $\rightarrow$ (c)

9. The magnetic moment, $m$, of [Col$_6$]$^{2+}$ (where L is an uncharged ligand) was determined to be 4.0 BM. (a) Give the valence electronic configuration of the complex. (b) State whether L is a strong- or weak field ligand and briefly defend your answer. (2 pts)

   (a)

   (b)
10. Assuming that $\beta$ for Ti$^{2+}$ (free ion) is 1030 cm$^{-1}$ and that 10Dq for Ti$^{2+}$ + OH$^-$ ligand is 8.9 x 10$^{-3}$ cm$^{-1}$, predict the frequencies of the two lowest energy bands of the electronic (d-d) spectrum of the complex ion, [Ti(OH)$_3$]$:^+$. Identify each band giving its transition (ground state $\rightarrow$ excited state)

<table>
<thead>
<tr>
<th>Band</th>
<th>Predicted frequency (cm$^{-1}$)</th>
<th>Transition involved</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

1.

2.

Free Ion Term State:  
S  P  D  F
States in an Oh filed:  
$A_1g$  $T_1g$  $Eg+T_2g$  $A_2g+T_1g+T_2g$

11. BONUS QUESTION: Carefully sketch and describe the most stable structure for each of the following. Please make them clear!

(a) Fe$_2$(CO)$_6$CH$_2$  
(b) Fe$_2$(cp)$_2$(CO)$_4$ (cp = cyclopentadienide)  

(2 pts)