Question 1  _____/12 points
Question 2  _____/09 points
Question 3  _____/24 points
Question 4  _____/12 points
Question 5  _____/12 points
Question 6  _____/15 points
Question 7  _____/16 points

TOTAL  _____/100 points

Name (printed)  __________________________

Signature  ________________________________

There are six pages (2-7) of questions in this exam. There is a periodic table on page 8.
(1) (3 points each, 12 points total) Please provide:

(1) the ML₆X₂-type assignment \( \text{ML}_3X_2^+ \)

(2) the formal oxidation state of the metal \( +3 \)

(3) the \( d^n \) electron count (i.e., give n) \( d^2 \)

(4) the total electron count of the metal complex \( 12 \text{ e}^- \)

\[ \begin{align*}
\text{Ta} & : 5 \text{ e}^- \\
\text{3L} & : 6 \text{ e}^- \\
2X & : 2 \text{ e}^- \\
\text{1L} & : 1 \text{ e}^- \\
& = 12 \text{ e}^- 
\end{align*} \]

(2) (3 points each, 9 points total) Please provide the indicated pKₐ values:

- MeOH \( 15 \)
- \( ^{\ominus} \text{NH}_4 \) \( 9 \)
- H-CN \( 9 \)
(3) (4 points each, 24 points total) Please provide all reagents/catalysts that are necessary to achieve the illustrated reactions.

1. **Acetaldehyde** to **Methyl vinyl ketone** with **H₂, PPh₃**.

2. **1-iodoarene** to **1-phenyl-1-propene** with **Pd(PPh₃)₄, (L₅PdO₂k), CO**.

3. **Iodomethane** to **1-phenyl-1-propene** with **Pd(PPh₃)₄, Ph₃SH, Heck**.

4. **Acetone** to **N-acetylacetone** with **NaBH₄, MeOH** or 1) LiAlH₄, Et₂O, 2) H₂O, work-up.

5. **Acetone** to **Acetophenone** with **H₂NNH₂, KOH, Δ** or **Zn/HCl**, Wolff-Kishner or Clemmensen reduction.

6. **Acetone** to **Acetic acid** with **CrO₃, H₂O/H⁺** or **KMnO₄**.
(4) (12 points) Please provide the best step-wise mechanism for the illustrated transformation.

\[
\text{catalytic}\quad\text{Ru} = \text{CH}_2 \quad \text{Ru} = \text{CH}_2
\]

\[
\text{ethylene}\quad\rightarrow\quad \text{ethylene}
\]

2 pts for each step.
(5) (12 points) Please provide an efficient and selective synthesis of cyclopentene, starting from the illustrated acetal. Give all key reagents/catalysts for each step of your synthesis. Do NOT draw the mechanism for each step.

Starting material: 

Target molecule: 

Retrosynthesis ("backwards synthesis")

Metathesis

\[ \text{wittig} \rightarrow \text{acetals} \rightarrow \text{oxidation} \]

Synthesis

\[ \text{metathesis} \rightarrow \text{wittig} \rightarrow \text{acetals} \rightarrow \text{oxidation} \]

+3 acetal hydrolysis
+3 alcohol oxidation with PCC
+3 wittig
+3 metathesis

[Partial credit given based on reasonable alternative steps]
(6) (15 points total)

\[
\begin{array}{c}
\text{Me} \\
\text{H}^+ \text{ (1 equiv)} \\
\text{H}_2\text{O} \\
\end{array} 
\rightarrow 
\begin{array}{c}
\text{MeH}_2\text{N} \\
- \text{Me} \\
\text{H} \\
\end{array} \text{C}=\text{O} 
\]

(a) (12 points) Please provide the best mechanism for the illustrated transformation, including all arrow pushing.

-2 points for a wrong step
-1 for minor error

Rxn is in acidic solution, should not have any O-charge in mechanism

(b) (3 points) For the hydrolysis of enamines and imines to aldehydes/ketones, it can be useful to utilize 1 equivalent, rather than a catalytic/sub-stoichiometric amount, of acid. Please provide a succinct explanation for this.

\[\text{H}^+ \text{ is consumed in rxn, the protonated amine in the product is not acidic enough to be deprotonated. Thus, the } \text{H}^+ \text{ is not recycled as a catalyst for the rxn, so 1 equiv of } \text{H}^+ \text{ becomes necessary to convert all of the reactants to products.}\]
(7) (16 points) Please provide the best mechanism for the illustrated transformation. Show and name each elementary step.