Answer all 19 questions (150 pts).

1. (16) **State** whether each of the following is aromatic or non-aromatic. In addition, give only the following data which enabled you to arrive at your conclusion: fully conjugated - yes or no; # pi-electrons involved in conjugation.
   
   a) ![E1.png](https://via.placeholder.com/150)
   b) ![E2.png](https://via.placeholder.com/150)
   c) ![E3.png](https://via.placeholder.com/150)
   d) ![E4.png](https://via.placeholder.com/150)

2. (6) Circle ALL of the following reactions that are possible:
   
a. Chlorobenzene + bromine in the presence of FeBr₃
b. Nitrobenzene + CH₃COCl, in the presence of AlCl₃
c. Phenol + CH₃COCl, in the presence of AlCl₃
d. Toluene + SO₃/sulfuric acid

3. (7) In each example shown, **circle** the benzene ring most likely to react with an electrophile. You need **not** explain your answer.

   a) ![E5.png](https://via.placeholder.com/150)
   b) ![E6.png](https://via.placeholder.com/150)

4. (12) State whether each of the following molecules is activated or deactivated compared to benzene. It is not necessary to explain why.

   a) ![E7.png](https://via.placeholder.com/150)
   b) ![E8.png](https://via.placeholder.com/150)
   c) ![E9.png](https://via.placeholder.com/150)
   d) ![E10.png](https://via.placeholder.com/150)

5. (12) State whether further electrophilic substitution of each of the following molecules would occur in the **ortho** / **para** or **meta** positions. It is not necessary to explain why.

   a) ![E11.png](https://via.placeholder.com/150)
   b) ![E12.png](https://via.placeholder.com/150)
   c) ![E13.png](https://via.placeholder.com/150)
   d) ![E14.png](https://via.placeholder.com/150)

6. (3) Circle the molecule in the following that would be most soluble in water.
7. (3) Circle the molecule in the following that would have the highest boiling point.

8. (9) For the compound shown below, show all the resonance forms that illustrate the effect of the group attached to the ring. You should show arrow-pushing to support your answer.

9. (4) Draw the carboxylic acid that could be reduced by LiAlH₄ to form the molecule shown:

10. (5) Place the following compounds in order of reactivity with Br₂/FeBr₃. Use #1 for most reactive to #4 for least reactive.

11. (3) True or False? The molecule shown would not react with KMnO₄ / H₂O.

12. (3) True or False? In Friedel-Crafts' acylations, rearrangements are not a problem.

13. (14) Draw out a synthetic sequence for the preparation of each of the following molecules, starting from
benzene and using any other necessary reagents.

a) 1,2-dichloro-4-nitrobenzene

\[ \text{b) } \]

\[ \text{HO} \]

\[ \text{O} \]

\[ \text{H} \]

\[ \text{O} \]

14. (4) Draw the missing Grignard reagent in the reaction shown:

\[ \text{Grignard} + \text{H}_2\text{C}=\text{O} \rightarrow \text{H}^+ \rightarrow \text{phenyl-ethanol} \]

15. (3) A carboxylic acid reacts much less readily with a nucleophilic reducing agent (such as \( \text{NaBH}_4 \)) than does an aldehyde. Give a reason why.

16. (3) True or False. The molecule shown is deactivated compared to benzene.

\[ \text{\( \text{F} \)} \]

\[ \text{\( \text{CONHCH}_3 \)} \]

17. (27.5) Show reasonable products, or missing reactants, for the following reactions.
18. (11) Name the following using IUPAC rules.

a) 

\[
\begin{array}{c}
\text{O} \\
\text{H}
\end{array}
\]

b) 

\[
\begin{array}{c}
\text{O} \\
\text{SO}_3, \text{H}_2\text{SO}_4
\end{array}
\]

c) 

\[
\begin{array}{c}
\text{OH}
\end{array}
\]

d) 

\[
\begin{array}{c}
\text{H}
\end{array}
\]

e) 

\[
\begin{array}{c}
\text{NBS, light}
\end{array}
\]

19. (4.5) **Circle** the intermediate shown below which would **not** result from electrophilic bromination of chlorobenzene at the *para* position.

a) 

\[
\begin{array}{c}
\text{Cl}
\end{array}
\]

b) 

\[
\begin{array}{c}
\text{Cl}
\end{array}
\]

c) 

\[
\begin{array}{c}
\text{Cl}
\end{array}
\]

d) 

\[
\begin{array}{c}
\text{Cl}
\end{array}
\]