1. Complete 5 out of the 6 following reactions, showing the main organic products. Cross one out or graded in order.

(a) \( \text{CH}_3 + \text{NaOH} \)

(b) \( \text{H}_3\text{C} - \text{CH} - \text{CH}_3 + \text{Br}_2 \text{ NBS} \)

(c) \( \text{Br} + \text{NaOH} \rightarrow \text{H}_2\text{O} \)

(d) \( \text{Cl} + \text{NaOH} \)

(e) \( \text{CH}_3 + \text{Br}_2, \text{FeBr}_3 \)

(f) \( \text{CN} + \text{Br}_2, \text{FeBr}_3 \)
2. Fill in the proper reagents A–F

\[
\text{benzene} + A \rightarrow \text{benzene} + B \rightarrow \text{benzene} + C \rightarrow \text{benzene} + D \rightarrow \text{benzene} + E \rightarrow \text{benzene} + F
\]

A_________  B_________  C_________

D_________  E_________  F_________

3. In the following reaction of chlorobenzene with nitric/sulfuric acid, complete the resonance structures below with the correct bonds. Then answer the questions underneath.

\[
\text{Cl}^* + \text{HNO}_3 \rightarrow \text{Cl}^* + \text{H}_2\text{SO}_4 \rightarrow \begin{array}{c}
\text{Cl} \swarrow \\
\text{H} \swarrow \\
\text{NO}_2 \searrow \\
\text{H} \searrow \\
\end{array}
\]

(a) Why is the sulfuric acid necessary? Nitric acid is already acidic, isn’t it? (Note: pKₐ (Nitric Acid) = -1.5, pKₐ (Sulfuric Acid) = -10).

(b) What is the reactive electrophile in the above reaction?

(c) If we used only pure (fuming) sulfuric acid, what would be the product(s)?

(d) Chlorine is o,p directing group but chlorobenzene is slower to react with nitric/sulfuric acid than benzene is. Why?
4. Starting with toluene, design syntheses, providing the correct reagents for the following transformations. Both processes can be accomplished with 2 steps, but there is more than one correct answer for each. Assume that ortho and para isomers can be separated.

5. Assign the NMR spectrum below to the molecule with the formula C$_8$H$_8$O$_2$ that reacts with nitric/sulfuric acid to make the meta product. Draw arrows to peaks. This is the reactant not the product. IR peak near 1700 cm$^{-1}$, 1620 cm$^{-1}$ and C-H sp$^2$
6. Draw the following alcohols:

(S)-2-butanol   allyl alcohol   isobutyl alcohol

7. Rank the order of acidity from 1 most acidic → 3 least acidic.
phenol   methyl alcohol   isopropyl alcohol
phenol   p-methylphenol   p-chlorophenol

8. Write the reagent that you would use to reduce the following carbonyl compounds over the arrow. Predict the product.

9. Write reagents over the arrows for these transformations:

10. What would be the product of
(a) 1-propanol + PBr₃ →
(b) cyclohexanol + POCl₃ →
(c) (S)-2-butanol + TosCl/pyridine followed by NaBr in DMF?
(d) 1-propanol + Jones Reagent (CrO₃-H₂SO₄) →
(e) 1-propanol + PCC →

11. Predict the products of the reaction of Phenyl MgBr with the carbonyl compounds below (assume acid workup):
(a) H₃C
(b) \[ \text{Ph} \]
(c) HO

12. The alcohol in 11.c would cause trouble. Why? How could we get around this problem?