1. [6 pts] Give a multistep synthesis for the conversion of benzene into the product shown below. *For each functional group transformation*, give all necessary other organic reactants, reagents, and catalysts; *For each functional group transformation*, show the structure of the organic product.

\[
\begin{align*}
\text{C}_6\text{H}_6 & \xrightarrow{\text{SO}_3, \text{H}_2\text{SO}_4} \text{C}_6\text{H}_5\text{SO}_3\text{H} \\
\text{C}_6\text{H}_5 & \xrightarrow{\text{Cl}_2} \text{C}_6\text{H}_5\text{Cl} \\
\text{C}_6\text{H}_5 & \xrightarrow{\text{FeO}_3} \text{C}_6\text{H}_5\text{SO}_3\text{H}
\end{align*}
\]

2. [4 pts] Provide a structural formula for the Lewis acid–Lewis base complex formed between AlCl₃ and acetyl chloride \((\text{CH}_3\text{C}=\text{O})\). Be sure to show nonzero formal charges.

\[
\begin{align*}
\text{CH}_3 - & \quad \text{C} \quad \text{O}^+ \\
\text{AlCl}_3 & \quad \text{C} \quad \text{O}^-
\end{align*}
\]

3. [3 pts] Concisely describe one type of important information about a compound that is given by mass spectrometry. If the molecular ion \((M^+)\) is detected, the molecular weight of the compound is known.

4. [7 pts] (a) How many peaks are there in the proton-decoupled \(^{13}\text{C}\)-nmr spectrum of the 1-tert-butyl-4-ethylbenzene?

(b) Provide a structural formula for 1-tert-butyl-4-ethylbenzene. For each carbon atom in the structure, clearly indicate the multiplicity that would be observed in the off-resonance decoupled \(^{13}\text{C}\)-nmr spectrum.

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{C} & \quad \text{C} \\
\text{CH}_2 & \quad \text{CH}_2
\end{align*}
\]

\[
\begin{align*}
\text{S} & = \text{singlet} \\
\text{d} & = \text{doublet} \\
\text{t} & = \text{triplet} \\
\text{q} & = \text{quartet}
\end{align*}
\]