This exam is worth 100 points out of a total of 600 points for Chemistry 3720/3720L. You have 50 minutes to complete the exam and you may use the attached spectroscopy sheet as needed. Good Luck.

1. (6 pts) The following spectral data belong to one of the five compounds shown below; circle the correct structure and match the $^1$H NMR data to that molecule.

$^1$H NMR (ppm): 2.34 (s, 3H), 3.30 (s, 3H), 4.80 (s, 2H), 7.16-7.48 (m, 4H)

$^{13}$C NMR (ppm): 21.6, 58.9, 74.8, 124.4, 128.1, 128.5, 129.3, 138.3, 138.7

IR (cm$^{-1}$): 760, 700

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2. (12 pts) An unknown organic compound has the formula C₆H₁₂O₂ from mass spectrometry data and the following signals in the ¹H and ¹³C spectra. Give a structure for the unknown compound that agrees with the NMR data and then match the ¹H NMR signals to the protons in your answer.

⁷H NMR (ppm): 1.13 (d, 6H, J = 6.9 Hz), 2.57 (q, 2H, J = 7.0 Hz), 3.19 (septet, 1H, J = 6.9 Hz), 3.67 (t, 2H, J = 7.0 Hz), 9.72 (t, 1H, J = 7.0 Hz)

¹³C NMR (ppm): 22.3 (double intensity), 43.5, 61.2, 75.5, 202.2

3. (12 pts) In the lab you have a bottle of benzene and all of the usual reagents and catalysts required to do organic synthesis. Beginning with benzene, provide an efficient synthesis of the following compounds by using any of the reactions and reagents seen thus far in Chemistry 3719 and 3720. Show the organic product(s) from each step of your syntheses; you may assume that isomer mixtures are separable.
4. (20 pts) *Give mechanistic explanations* for the formation of the products and the regiochemical outcomes in the following reactions (i.e. draw the mechanisms and use resonance structures to explain the products).

a) \[
\begin{array}{c}
\text{CH}_3\text{C}_6\text{H}_4^+ \quad \text{H}_2\text{SO}_4, 0 \, ^\circ\text{C} \quad \text{C}_6\text{H}_4\text{CH}_3^- \\
\end{array}
\]

only isomer formed

b) \[
\begin{array}{c}
\text{CH}_3\text{O}_2\text{C}_6\text{H}_4^+ \quad \text{Cl}\text{CH}_2CO} \quad \text{AlCl}_3 \quad \text{CH}_3\text{O}_2\text{C}_6\text{H}_4^+ \\
\end{array}
\]

only isomer formed
5. (12 pts) From the $^1$H and $^{13}$C NMR data given below, provide the structure of the unknown material that has the molecular formula C$_{14}$H$_{20}$O$_2$. Match the $^1$H NMR signals to the protons in the unknown.

$^1$H NMR (ppm): 1.09 (d, 6H, $J = 6.9$ Hz), 1.35 (s, 9H), 2.67 (septet, 1H, $J = 6.9$ Hz), 7.21 (d, 2H, $J = 7.0$ Hz), 7.56 (d, $J = 7.0$ Hz)

$^{13}$C NMR (ppm): 19.1 (double intensity), 31.3 (triple intensity), 33.6, 34.2, 121.2 (double intensity), 125.4 (double intensity), 148.1, 148.2, 175.4

Mass spectrum: M$^+$ = 220.3
Infra-Red: 1740, 800 cm$^{-1}$
6. (20 pts) Provide the major organic product(s) from each step of the following reaction sequences.

a. ![OH](image)
   1. Br₂, FeBr₃
   2. NaOH

b. ![NO₂](image)
   1. HNO₃, H₂SO₄
   2. excess Sn, HCl

c. ![ ](image)
   1. CH₃COCl, AlCl₃
   2. Br₂, FeBr₃
   3. Zn, HCl

d. ![CH₃](image)
   1. SO₃, H₂SO₄
   2. KMnO₄

e. ![Cl](image)
   1. HNO₃, H₂SO₄
   2. Sn, HCl
7. (8 pts) **Give a detailed mechanism** (including resonance structures for the intermediate) for the formation of the product in the following reaction.

![Reaction Mechanism](image)

8. (10 pts) On the axis given below, **draw the approximate $^1H NMR spectrum** for the following molecule. **Label** which signals belong to which protons.

![NMR Spectrum](image)