There are 7 pages and 250 pts on this exam. Please read each question carefully before answering. Be clear and concise in your explanations, and draw your structures carefully to depict any necessary stereochemistry.

1. (10 pts) Rank the following compounds (from 1 to 5) in order of increasing acidity (1 = least acidic):

\[ \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \]

\[ \text{CH}_2\text{OH} \quad \text{CH}_3 \quad \text{OCH}_3 \quad \text{CH}_3 \quad \text{OH} \]

2. (9 pts) Rank the following compounds (from 1 to 3) in order of increasing value of the C-H stretch in their infrared spectra in cm\(^{-1}\) (1 = smallest value of the IR stretch):

\[ \text{RC} = \text{C} - \text{H} \quad \text{R} \quad \text{R} \quad \text{R} \quad \text{CH}_3 \]

3. (8 pts) Rank the following compounds (from 1 to 4) in order of increasing value of the C=O stretch in their infrared spectra (1 = smallest value of the IR stretch):

\[ \text{H}_3\text{C} \quad \text{O} \quad \text{OCH}_3 \quad \text{H}_3\text{C} \quad \text{O} \quad \text{CH}_3 \quad \text{H}_3\text{C} \quad \text{C} \quad \text{Cl} \]

4. (10 pts) Rank the following compounds (from 1 to 5) in order of increasing value of the proton NMR chemical shift (\(\delta\)) in ppm for the H indicated in bold (1 = smallest value of \(\delta\)):

\[ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \]

\[ \text{OCH}_3 \quad \text{CH}_3 \quad \text{CH}_3 \quad \text{H} \]

\[ \text{Ph} \]

\[ \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \]

\[ \text{CH}_2\text{OH} \quad \text{CH}_3 \quad \text{OCH}_3 \quad \text{CH}_3 \quad \text{OH} \]
5. (15 pts) Each of three bottles (A, B, and C) is labeled only “C₆H₁₂” and contains a colorless liquid. Identify each compound based on the spectroscopic and reactivity information provided below. And explain your reasoning.

(a) Compound A: ¹H NMR: δ 1.66 (s); reacts with Br₂ in CCl₄; IR: no significant absorption in the range 1620 - 1700 cm⁻¹

(b) Compound B: ¹H NMR: δ 1.07 (6H, d, J = 7 Hz); δ 1.70 (3H, d, J = 1.5 Hz); δ 2.20 (1H, septet, J = 7 Hz); δ 4.60 (2H, d, J = 1.5 Hz); IR: 1642, 891, 3080 cm⁻¹

(c) Compound C: ¹H NMR: δ 1.40 (s); does NOT react with Br₂ in CCl₄

6. (15 pts) To which of the compounds below does the following ¹³C-NMR spectral data belong. Explain.

δ 15.5 (quartet), δ 20.1 (quartet), δ 60.7 (triplet), δ 99.6 (doublet)

\[
\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_3 \quad \text{CH}_3\text{CH}_2\text{O} \quad \text{CH}_3\text{OCH}_2\text{CH}_2\text{OCH}_3
\]

A \quad B \quad C
7. (36 pts) Provide the products of the following reactions. If there is more than one product, predict which will be major.

(a) \[ \text{H}_3\text{C} \quad 1) \text{Br} \\
    \quad 2) \text{H}_3\text{O}^+ \]

(b) \[ \text{O} \\
    1) \text{LDA, } -78^\circ\text{C} \\
    2) \text{OCH}_3 \]

(c) \[ \text{CH}_3\text{O} \quad 1) \text{NaOCH}_3 \\
    \quad 2) \text{H}_2\text{O} \]

(d) \[ \text{CH}_3 + \text{CN} \]

(e) \[ \text{NaOH} \quad \text{excess Br}_2 \]

(f) \[ 1) \text{NaOH} \\
    2) \text{CH}_3\text{C} \text{H}_3 \text{Br} \\
    3) \text{H}_3\text{O}^+ \]

(g) \[ \text{CH}_3\text{O} + \text{OCH}_3 \]

(h) \[ \text{OCH}_3 \\
    1) \text{NaOCH}_3 \\
    2) \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} \\
    3) \text{H}_3\text{O}^+, \text{heat} \]

(i) \[ \text{Br}_2 \]
8. (25 pts) Provide all reagents for the following reactions. In some cases, more than one step may be required.

9. (30 pts) Provide the products you would obtain from reaction of β-D-galactose with the following reagents:
10. (45 pts) Provide syntheses for these compounds with reagents and conditions. Assume that you can separate isomers.

(a) Start with \(\text{CH}_3\text{O}_2\text{C} - \text{CO}_2\text{CH}_3\) and prepare [image of a compound with a cyclohexyl ring and a carboxyl group].

(b) Start with [image of a compound with two hydroxyl groups and a methanol group] and prepare [image of a compound with three hydroxyl groups and a carboxyl group].

(c) Start with [image of a cyclohexane ring with two carbonyl groups] and prepare [image of a cyclohexane ring with three carbonyl groups and a methyl group].
11. (12 pts) Sucrose is a disaccharide that is shown below.

(a) What sugar units make up sucrose? 
(b) What kind of glycosidic linkage is depicted above by the bond marked A? 
(c) Is sucrose a reducing or non-reducing sugar? 
(d) What anomer stereochemistry is depicted above by B?

12. (15 pts) Suggest a structure for the m/z = 87 ion in the electron impact mass spectrum of 2-methyl-2-pentanol, and provide a mechanism for its formation.
13. (20 pts) Provide a mechanism for the following transformation.

\[
\begin{align*}
\text{H}_3\text{C} & \text{C} = \text{OCH}_3 + \text{C}_6\text{H}_5\text{C} = \text{OCH}_3 \\
1) \text{1 eq NaOCH}_3 & 2) \text{H}_3\text{O}^+ \text{workup} \\
\text{C}_6\text{H}_5\text{C} = \text{OCH}_3 &
\end{align*}
\]