Teachers: E. Cadieux, I. Dionne, D. Montecalvo

Student Name and Number: ____________________________

Instructions:

1. This examination package has 10 questions and 17 pages. It is your responsibility to ensure that there are no pages missing.

2. Please write your name and student number before beginning the exam.

3. Answer all questions directly on the exam pages in the spaces provided.

4. Write in ink or you may lose the right to grieve the exam grade.

5. Write clearly. Illegible answers will result in grade deductions.

6. **Do not detach** any of the sheets in this package.

7. Two blank pages are provided at the end of the examination package for your **rough work. Your teacher will not look at any work written on those pages.**

8. **Calculators are not permitted.**

9. Molecular models are permitted but may not be passed to other students.

10. Unless otherwise indicated, structural formulas must be shown with all hydrogen atoms, except in ring structures where bond-line formulas are permitted.


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1. Provide appropriate names or structural formulas for the following: (16 marks)

(a) ![Structural formula](image)

(b) \( \text{CH}_3-\text{CH}_2-\text{CH}_2-\text{N}-\text{CH}_2-\text{CH}_3 \)

(c) 4-oxo-3-chlorobutanoic acid

(d) \( \text{CH}_3-\text{CH}_2-\text{CH}-\text{CH}_2-\text{C}-\text{Br} \)

(e) benzyl benzoate

(f) \( \text{CH}_3-\text{CH}-\text{CH}_2-\text{C}-\text{NH} \)

(g) ethyl phenyl ether

(h) ![Structural formula](image)
2. Propose a structure for each of the following compounds based on the $^1$H NMR information. (8 marks)

(a) C$_5$H$_{10}$O
   - 0.95 δ doublet
   - 2.10 δ singlet
   - 2.43 δ septet

(b) C$_4$H$_6$Cl$_2$
   - 1.4 δ pentet (5 peaks)
   - 2.1 δ triplet
3. An unknown chemical, $X$, whose molar mass is 169, produces the following infrared, $^1$H NMR and $^{13}$C NMR spectra. Hydrolysis of $X$ produces two products, $Y$ and $Z$. The molar mass of $Y$ is 72 and the spectra are provided below. The molar mass of $Z$ is 115. Infrared peaks: 1715 cm$^{-1}$ and 3290, 3350 cm$^{-1}$. Propose structural formulas for $X$, $Y$ and $Z$. Your grade will be based on the thoroughness of your analysis and not solely on the final answer. Write directly on the spectra themselves.
Proposed structures:

Compound X

Compound Y

Compound Z
4. (a) Why are NH₃ and CH₃NH₂ no longer nucleophiles in acidic solution?  
(b) Why does a Grignard reagent not attack and bond to the carbonyl carbon of a carboxylic acid?  
(c) Only 15% of 2,4-pentanedione exists as the enol tautomer in water, but 92% exists as the enol tautomer in hexane. Explain why this is so.
5. Give a detailed step-by-step mechanism to show how the products of the following reaction are formed. Used the curved arrow convention to show electronic movements.

(a) \[
\text{reaction}
\]

(b) \[
\text{reaction}
\]
6. Rank the following compounds in order of decreasing solubility in water. 

Do not explain.

Answer: _____ > _____ > _____.

7. (a) Indicate the aldehyde or ketone from which the following compound would be formed by an aldol addition.

2-ethyl-3-hydroxyhexanal
(b) What carbonyl compound and what phosphonium ylide are required in the last step of the Wittig synthesis of the following alkene? Provide two routes to achieve this synthesis.

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}=-\text{C}-\text{CH}_3
\]

\[
\text{CH}_3
\]

(c) The Gabriel synthesis is used to make what class of compound (functional group)? (1 mark)
8. Provide brief answers to the following questions, concerning your laboratory work. (6 marks)

(a) What technique did you use to separate the clove oil (eugenol) from the ground cloves?

(b) What apparatus was used to remove a volatile solvent from a final nonvolatile product, other than a distillation?

(c) What color is β-carotene? Is this compound uv-visible active?

(d) Name 2 techniques, other than spectroscopy (IR, NMR, MS, uv-vis), that can be used to verify the identity of a product.
9. Supply missing major organic products. (25 marks)

(a) \[2 \overset{\text{NaOH}}{\text{H}_2\text{O}} \overset{\text{heat}}{\rightarrow} \text{CH}_3\text{C} = \text{O} \] 

(b) \[\text{CH}_3\text{CH}-\text{CH}_2\overset{\text{Br}_2, \text{NaOH}}{\text{H}_2\text{O}} \rightarrow \text{CH}_3\text{CH}-\text{CH}_2\text{CO} \] 

(c) \[\overset{\text{H}_2\text{C}-\text{CH}-\text{P}^+\text{Ph}_3}{\rightarrow} \text{C} = \text{O} \rightarrow \text{CH}_3\text{CH} = \text{CH}_3 \text{ + } \] 

(d) \[\overset{\text{NaNO}_2, \text{HCl}}{\text{0°C}} \overset{\text{HBF}_4}{\text{heat}} \rightarrow \overset{\text{CH}_3\text{CH}_2\text{MgBr} + \overset{1. \text{ether}}{\rightarrow} \overset{2. \text{H}_3\text{O}^+}{\text{phenyl}}}{\rightarrow} \] 

(e) \[\overset{\text{1. ether}}{\rightarrow} \overset{\text{2. H}_3\text{O}^+}{\rightarrow} \text{CH}_3\text{CH}_2\text{MgBr} + \overset{\text{1. ether}}{\rightarrow} \overset{\text{2. H}_3\text{O}^+}{\rightarrow} \text{CH}_3\text{CH} = \text{CH}_2\text{C} = \text{O} \] 

(f) \[\overset{\text{CH}_3\text{C} = \text{O} \text{ + } \overset{\rightarrow}{\overset{\rightarrow}{\rightarrow}} \text{NH}_3}{\text{H}_2\text{Pt}} \overset{\text{ethanol}}{\rightarrow} \text{CH}_3\text{C} = \text{O} \text{ + } \overset{\rightarrow}{\overset{\rightarrow}{\rightarrow}} \text{NH}_3 \] 

(g) \[\overset{\text{H}_2/\text{Pt}}{\text{ethanol}} \rightarrow \text{CH}_3\text{O} - \text{CH}_2\text{CH}_2\text{C} = \text{H} \]
(h) \[ \text{CH}_3\text{CH}_2\text{C}≡\text{CH} \rightarrow 2 \text{HBr} \]

(i) \[ \text{CH}_3\text{CH}-\text{CH}-\text{CH}_3 + (\text{CH}_3)_2\text{CuLi} \rightarrow -78^\circ\text{C} \text{ ether} \]

(j) \[ \text{CH}_3\text{C}-\text{CH}_2\text{CN} \rightarrow \text{KOH} \text{ H}_2\text{O}, \text{heat} \rightarrow \text{CH}_3\text{C}-\text{CH}_2\text{CN} + \text{NH}_3 \]

(k) \[ \text{CH}_3\text{CH}_2\text{C}≡\text{CH} \rightarrow \text{Cl}_2 \rightarrow 1. \text{excess } \cdot\text{OH, heat} \rightarrow 2. \text{H}_2\text{O}^+ \]

(l) \[ \text{CH}_3\text{CH}≡\text{CH-CH}_3 + \text{CH}_3\text{C}-\text{O-OH} \rightarrow \text{CH}_3\text{Cl}_2 \rightarrow \text{+} \]

(m) \[ \text{CH}_3\text{C}-\text{CH(N(CH}_3)_3\text{)}^+\text{OH} \rightarrow 160^\circ\text{C} \rightarrow \text{+} \]
(n) \[ \text{CH}_3 + \text{C}_6\text{H}_5\text{Cl} + \text{AlCl}_3 \xrightarrow{\text{heat}} \]

(o) \[ \text{CH}_3\text{COCl} \xrightarrow{1. \text{excess LiAlH}_4, 2. \text{H}_3\text{O}^+} \]

(p) \[ \text{CH}_2=\text{CH}-\text{COCl} \xrightarrow{1. \text{LiAlH}-(\text{O-}{\text{t}}-\text{Bu})_3, \text{ether, } -78^\circ\text{C}, 2. \text{H}_2\text{O}} \]

(q) \[ \text{O} + \text{HCN} \xrightarrow{1. \text{LiAlH}_4, 2. \text{H}_2\text{O}} \]

(r) \[ \text{CH}_3 \xrightarrow{\text{Na}_2\text{Cr}_2\text{O}_7, \text{H}_2\text{SO}_4, \text{heat}} \]
10. Show how you would carry out the following syntheses. You must begin with the indicated chemical(s) and you may use any necessary inorganic or organic reagents. All your reactions must produce the desired products in good yields and in a reasonably pure state.

(a) \[
\text{trans-}\text{cyclohexanol from cyclohexyl bromide}
\]

(b) 3-heptanone from 1-propanol

(c) \[
\text{propanoic acid from ethanol}
\]
For your **rough work. Your teacher will not look at any work written on this page.**
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