Carboxylic Acids

Draw structures corresponding to each of the following IUPAC names.

1. 2-propylpentanoic acid
   
   Answer:
   
   ![Structure of 2-propylpentanoic acid]

2. m-chlorobenzoic acid
   
   Answer:
   
   ![Structure of m-chlorobenzoic acid]

3. \( \text{HOOC(CH}_2\text{)}_3\text{COH} \) glutaric acid
   
   Answer: pentanedioic acid

4. \( \text{C}_6\text{H}_4\text{OH} \) salicylic acid
   
   Answer: \( o \)-hydroxybenzoic acid
Consider the data in the Table below to answer the following questions:

<table>
<thead>
<tr>
<th>Acidity of Substituted Benzoic and Acetic Acids</th>
<th>$pK_a$ at 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y - \text{CH}_2\text{COOH}$</td>
<td>$Y - \text{C}_6\text{H}_4\text{COOH}$</td>
</tr>
<tr>
<td>$pK_a$</td>
<td>$pK_a$</td>
</tr>
<tr>
<td>Y</td>
<td>meta</td>
</tr>
<tr>
<td>H</td>
<td>4.75</td>
</tr>
<tr>
<td>CN</td>
<td>2.47</td>
</tr>
<tr>
<td>OCH$_3$</td>
<td>3.57</td>
</tr>
</tbody>
</table>

5. Draw the structure of the strongest acid in the table above.

**Answer:** NC-CH$_2$-COOH

6. Which of the acids in the table above has the strongest conjugate base?

**Answer:** CH$_3$COOH

7. Explain why cyanoacetic acid and methoxyacetic acid are more acidic than their correspondingly substituted benzoic acid counterparts.

**Answer:** Electron-withdrawing groups, like –CN and –OCH$_3$, inductively withdraw electron density, which stabilizes the resulting carboxylate anion and, thus, increases the acidity of the carboxylic acid. These inductive effects are strongly dependent on distance. The –CN and –OCH$_3$ substituents are closer to the carboxylate in the substituted acetic acids than in the substituted benzoic acids, so their effect is greater.

8. Even through the *para* position is one carbon farther from the carboxy group than the *meta* position, $p$-cyanobenzoic acid is *more* acidic than $m$-cyanobenzoic acid. Explain the differences in acidity between $p$-cyanobenzoic acid and $m$-cyanobenzoic acid.

**Answer:** In $p$-cyanobenzoic acid, the negative charge of the carboxylate can be better stabilized than in the *meta* isomer because the electron-withdrawing cyano group polarizes the benzene ring and places a positive charge next to the negatively charged carboxyl group. The same polarization occurs in $m$-cyanobenzoic acid, but the effect is not as great because the charge is one carbon farther away from the carboxy group.
9. Explain the differences in acidity between \( p \)-methoxybenzoic acid and \( m \)-methoxybenzoic acid.

**Answer:** \( p \)-Methoxybenzoic acid is less acidic than \( m \)-methoxybenzoic acid because the carboxyl group is directly conjugated, through the benzene ring, with the electron-donating oxygen of the methoxy group. This destabilizes the \( p \)-methoxybenzoate anion relative to the \( m \)-methoxybenzoate anion by placing two negative charges on the carboxylate group.

\[
\begin{align*}
\text{versus}
\end{align*}
\]

Consider the data below to answer the following questions.

When \( \text{CO}_2 \) is bubbled through an ether solution of benzylmagnesium bromide, and the resulting mixture is acidified, phenylacetic acid is produced. Any unreacted benzylmagnesium bromide is converted to toluene in the acidification step.

10. Write the complete reaction sequence for the process described above.

**Answer:**

\[
\begin{align*}
\text{CH}_2\text{MgBr} + \text{CO}_2 & \xrightarrow{1. \text{ether}} \text{CO}_3^- \text{CH}_2\text{COH} + \text{CH}_3\text{C} = \text{H}^+ \\
& \xrightarrow{2. \text{H}_3\text{O}^+} \\
\end{align*}
\]

11. How could you separate phenylacetic acid from toluene?

**Answer:** Extract the ether solution containing the mixture of products with a dilute aqueous solution of sodium hydroxide. This converts phenylacetic acid to its carboxylate salt, which will dissolve in the aqueous layer. The toluene will remain in the ether layer. Separate the aqueous and organic layers, acidify the aqueous layer, and extract with an organic solvent to recover the phenylacetic acid.

12. This reaction is described as a ____________ process.

a. carbonylation  

b. **carboxylation**  

c. carbanilolation  

d. cationation
What is the order of increasing acidity for the following compounds? (least to most)

13. 

- **COOH**
- **COOH**
- **COOH**
- **COOH**

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
</tbody>
</table>

- a. IV, I, III, II
- b. III, II, I, IV
- c. II, III, I, IV
- d. III, II, IV, I

**Answer:** b

14. 

- **COOH**
- **COOH**
- **COOH**
- **CH₃COOH**

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</table>

- a. IV, I, III, II
- b. IV, II, III, I
- c. II, III, I, IV
- d. I, III, II, IV

**Answer:** a
Give the major organic product(s) for each of the following reactions or sequences of reactions. Show all relevant stereochemistry.

15. \[ \text{KMnO}_4 \xrightarrow{\text{H}_2\text{O}^+} \]

Answer:

16. \[ \text{1. NaCN} \]
\[ \text{2. NaOH, H}_2\text{O, heat} \]
\[ \text{3. H}_3\text{O}^+ \]

Answer:

17. \[ \text{1. LiAlH}_4, \text{THF, heat} \]
\[ \text{2. H}_3\text{O}^+ \]

Answer:
18. \[
\text{CH}_2\text{Br} \xrightarrow{\text{1. NaCN, acetone}} \text{CH}_2\text{COOH} \\
\text{CH}_2\text{Br} \xrightarrow{\text{2. } \text{H}_3\text{O}^+, \text{heat}} \text{CH}_2\text{COOH}
\]

19. \[
\text{COOH} \xrightarrow{\text{1. BH}_3, \text{THF}} \text{CH}_2\text{OH} \\
\text{COOH} \xrightarrow{\text{2. } \text{H}_3\text{O}^+} \text{CH}_2\text{OH}
\]

20. \[
\text{OH} \xrightarrow{\text{CrO}_3, \text{H}_3\text{O}^+} \text{COOH} \\
\text{OH} \xrightarrow{\text{CrO}_3, \text{H}_3\text{O}^+} \text{COOH}
\]
Answer:

28.

Answer:

29.

Answer:
Choose the best reagent(s) for carrying out the following conversions from the list below. Place the letter corresponding to the best choice in the blank to the left of the conversion.

- KMnO₄, H₂O⁺
- Tollens' Reagent
- NaBH₄, ethanol
- 1. BH₃  2. H₂O⁺
- 1. CH₃MgBr, ether  2. H₂O⁺
- CrO₃, H₂SO₄, H₂O
- 1. Mg, ether  2. CO₂  3. H₂O⁺
- NaCN  2. H₂SO₄, H₂, heat
- O₃, then Zn and HOAc
- CH₃I

35. CH₃CH=CHCH₂COOH → CH₃COOH + HOOCCH₂COOH
   Answer: a

36. __________ → __________
   Answer: g

37. __________ → __________
   Answer: d

38. __________ → __________
   Answer: b

39. __________ → __________
   Answer: e
Carboxylic acids are synthesized from alkyl halides via Grignard reagent carboxylation or nitrile hydrolysis. Choose the best method for effecting each of the following conversions. Explain each of your choices. If neither method is appropriate, explain.

40.  

\[
\begin{array}{c}
\text{Br} \\
\text{CH}_3
\end{array} \xrightarrow{\text{Grignard reagent carboxylation}}
\begin{array}{c}
\text{COOH} \\
\text{CH}_3
\end{array}
\]

*Answer:* Since $S_N2$ displacements do not occur at tertiary alkyl halides the Grignard reagent carboxylation is the best method for carrying out this conversion.

41.  

\[
\begin{array}{c}
\text{I} \\
\text{CH}_2\text{CH}_2
\end{array} \xrightarrow{\text{Nitrile hydrolysis}}
\begin{array}{c}
\text{COOH} \\
\text{CH}_2\text{CH}_2
\end{array}
\]

*Answer:* Amine protons interfere with the formation of Grignard reagents, so nitrile hydrolysis is the best method for carrying out this conversion.