Answer all the questions below as fully as you can then check your answers

1. Draw and name the functional group present in all carboxylic acids.
2. Draw the structure of the first 4 carboxylic acids.

a. The first 4 carboxylic acids are soluble in water but the solubility decreases as the carboxylic acid molecules get larger. Explain this observation.

b. What is the strongest type of intermolecular bonding is present between carboxylic acids and water molecules?

i. Draw a diagram to show this intermolecular bonding between two water molecules and a carboxylic acid.

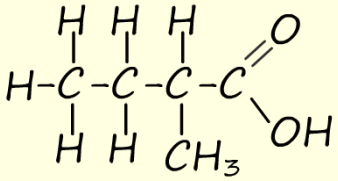
c. Carboxylic acid molecules have a higher than expected melting and boiling point based on their molecular mass. Explain why.

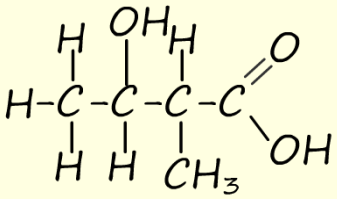
i. Draw a diagram to show dimerisation between two carboxylic acid molecules.

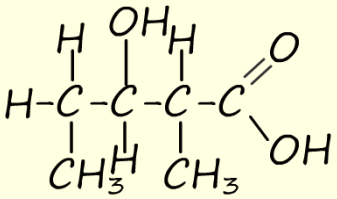
3. Carboxylate ions are resonance stabilised ions. Explain what this means and draw a diagram to show the two resonance structures for the ethanoate ion.

a. Draw a diagram to show how these two resonance structures can be represented by a single resonance hybrid structure.

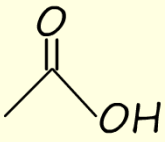
4. Name the carboxylic acids shown below:

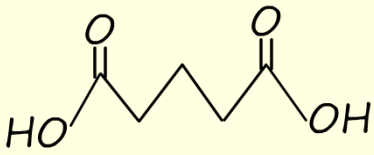






$CH_3CH_2CClHCOOH$





5. Write word and symbolic equations to show the neutralisation reaction between sodium hydroxide and ethanoic acid.

a. Write a word and symbolic equation to show the products of the above reaction if an excess of hydrochloric acid is added to the reaction mixture.

b. Explain how long chain insoluble carboxylic acids can be purified.

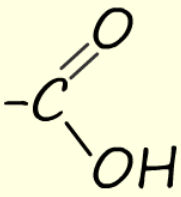
6. Write an equation to show the reaction of methanoic acid with calcium carbonate.

a. Write an equation to show the reaction of ethanoic acid with sodium hydrogencarbonate.

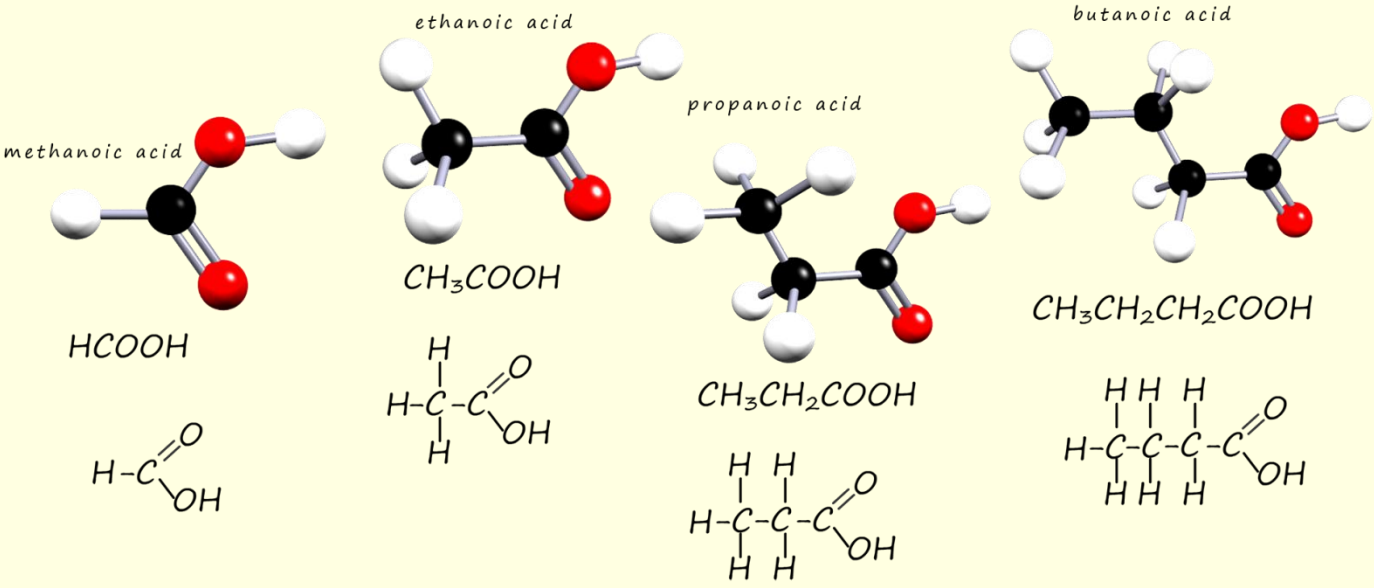
b. How can the results of this reaction be used as a simple test for carboxylic acids?

Answers

1. Draw and name the functional group present in all carboxylic acids.
   All carboxylic acids contain the carboxyl functional group, shown opposite



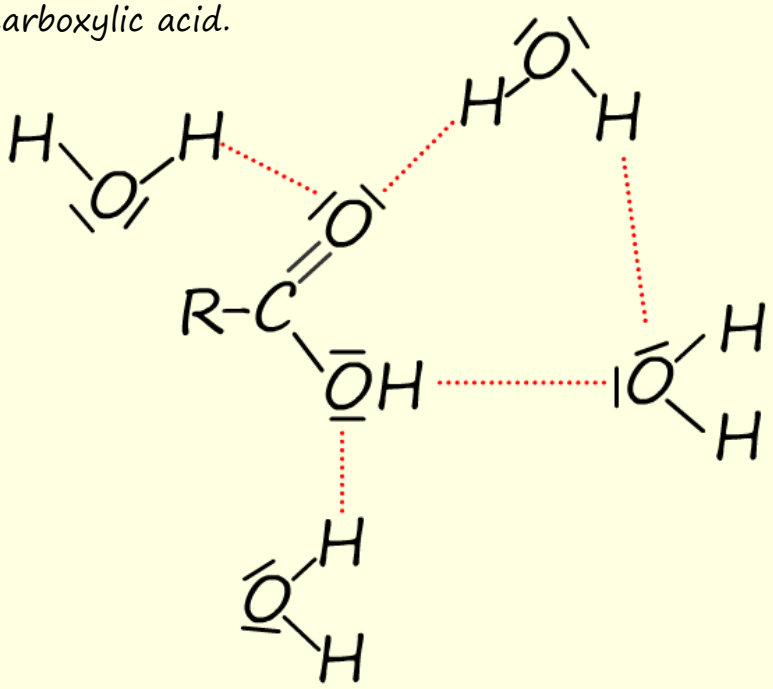
2. Draw the structure of the first 4 carboxylic acids.



a. The first 4 carboxylic acids are soluble in water but the solubility decreases as the carboxylic acid molecules get larger. Explain this observation.
   In order to dissolve a solute must interact in some way with a solvent. Carboxylic acids will form hydrogen bonds with water molecules. However as the carbon chain length grows in carboxylic molecules the properties of the covalently bonded non-polar portion of the molecule will start to dominate the properties, covalent non-polar molecules will NOT form hydrogen bonds with water molecules and so long chain carboxylic acids are insoluble in water.

b. What is the strongest type of intermolecular bonding is present between carboxylic acids and water molecules?
   Hydrogen bonding.

i. Draw a diagram to show this intermolecular bonding between two water molecules and a carboxylic acid.

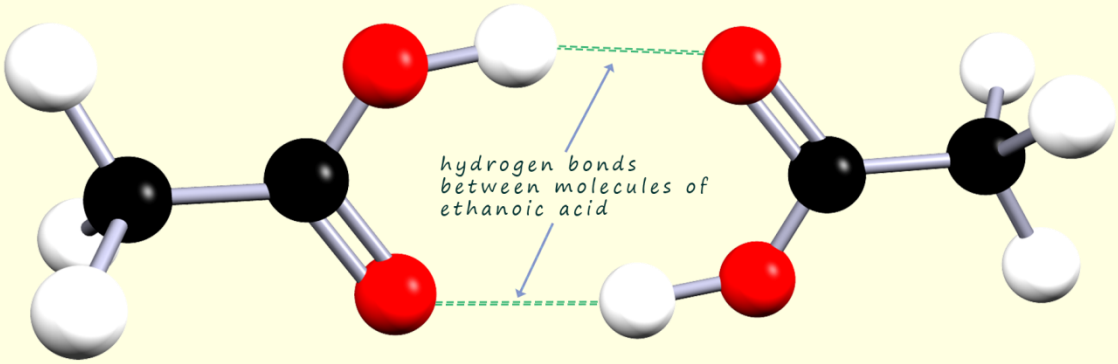


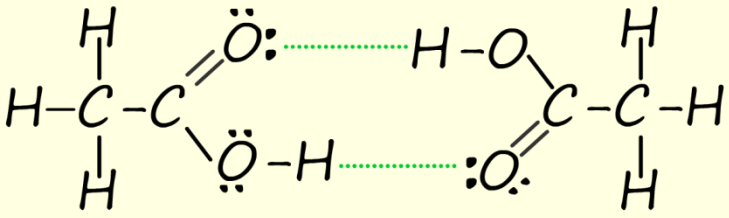
c. Carboxylic acid molecules have a higher than expected melting and boiling point based on their molecular mass. Explain why.

Molecules of carboxylic acids can form hydrogen bonds with each other to form dimers.

i. Draw a diagram to show dimerisation between two carboxylic acid molecules.

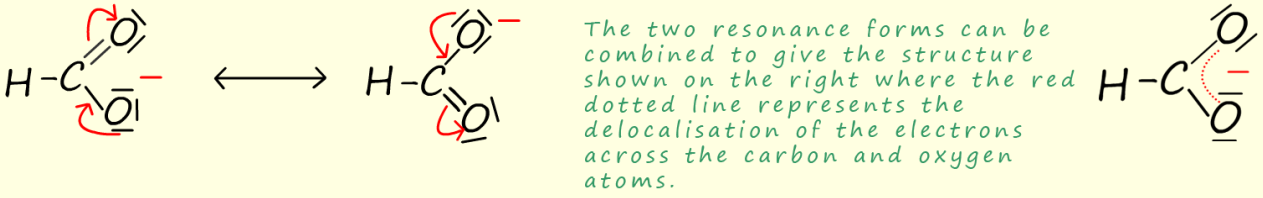
Carboxylic acids have strong intermolecular hydrogen bonding between the molecules. Most carboxylic acids exist as a pair of dimers with two hydrogen bonds between adjacent molecules.





3. Carboxylate ions are resonance stabilised ions. Explain what this means and draw a diagram to show the two resonance structures for the ethanoate ion.

Resonance is where the electrons are delocalised and free to move but the nuclei stay in place. The more resonance structures a molecule has the more stable it will be.

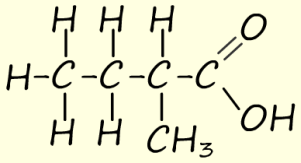


The two resonance forms can be combined to give the structure shown on the right where the red dotted line represents the delocalisation of the electrons across the carbon and oxygen atoms.

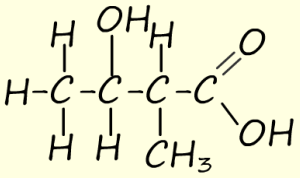
a. Draw a diagram to show how these two resonance structures can be represented by a single resonance hybrid structure.

See answer above

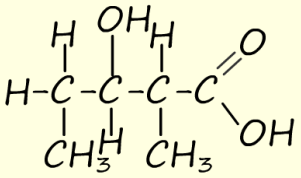
4. Name the carboxylic acids shown below:



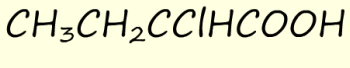
2-methylbutanoic acid



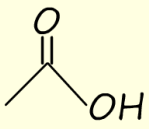
3-hydroxy-2-methylbutanoic acid



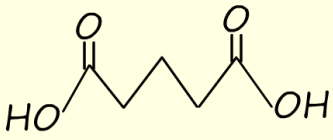
3-hydroxy-2-methylpentanoic acid



2-chlorobutanoic acid



ethanoic acid



pentanedioic acid

5. Write word and symbolic equations to show the neutralisation reaction between sodium hydroxide and ethanoic acid.

Sodium Hydroxide + ethanoic acid ⟶ sodium ethanoate + water

$NaOH + CH_3COOH \longrightarrow CH_3COO^-Na^+ + H_2O$

a. Write a word and symbolic equation to show the products of the above reaction if an excess of hydrochloric acid is added to the reaction mixture.

Addition of an excess of hydrochloric acid to sodium ethanoate will simply add hydrogen ions to the ethanoate ion to form ethanoic acid. Ethanoate ions are the conjugate base of ethanoic acid.

$CH_3COO^-Na^+ + HCl \longrightarrow CH_3COOH + NaCl$

b. Explain how long chain insoluble carboxylic acids can be purified.

You can purify by following the equations in part a. Addition of a base to a long chain insoluble carboxylic acid will form the soluble salt which can then be separated out from any other insoluble material present by filtration. Acidification will then reform the long chain carboxylic acid.

6. Write an equation to show the reaction of methanoic acid with calcium carbonate.

$2HCOOH + CaCO_3 \longrightarrow (HCOO)_2Ca + H_2O + CO_2$

Methanoic acid + calcium carbonate → calcium methanoate + water + carbon dioxide

a. Write an equation to show the reaction of ethanoic acid with sodium hydrogencarbonate.

$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$

b. How can the results of this reaction be used as a simple test for carboxylic acids?

Carboxylic acids despite being weak acids are able to displace CO_2 from carbonate/hydrogencarbonate. The fizzing due to the addition of a carboxylic acid is a very simple first test to identify the presence of a carboxylic acid.