Analysis

(d) Boiling points of alcohols increase with increasing length of hydrocarbon chain. Melting points decrease with increasing length of hydrocarbon chain for the first three alcohols. *n*-butanol is less soluble in water than are the first three alcohols.

Synthesis

(e) The properties of primary alcohols are a combination of the properties of its polar OH group and its nonpolar hydrocarbon component. Molecular models show the increasing length of the nonpolar component and corresponding trends in properties.

INVESTIGATION 1.7.1 PROPERTIES OF CARBOXYLIC ACIDS

(Page 87)

Question

(a) (Sample answers) How does the length of the hydrocarbon chain in a carboxylic acid affect its melting and boiling points, its solubility, and its reactions with bases and oxidizing agents?

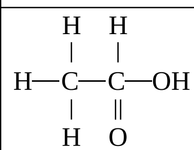
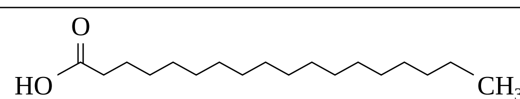
What are the similarities and differences in several properties of two carboxylic acids of different molecular size?

Prediction

(b) (Sample answer) Stearic acid has a much longer hydrocarbon chain than does acetic acid; thus, stearic acid is more nonpolar than acetic acid and will be less soluble in a polar solvent such as water, and more soluble in a nonpolar solvent such as vegetable oil. Stearic acid will also have a higher melting point because its long hydrocarbon chain allows additional intermolecular forces of attraction (van der Waals). Acetic acid will react readily with the base, but stearic acid will react less readily because it is less soluble in the aqueous solution of the base. Neither acid will react with the potassium permanganate because the carboxyl group does not readily gain oxygen atoms or lose hydrogen atoms.

Evidence

(c) and (d)

Property	Acetic acid	Stearic acid
IUPAC name	ethanoic acid	octadecanoic acid
structural diagram	 ethanoic acid	 stearic acid
molar mass	60.05 g/mol	284.50 g/mol
solubility	soluble in water (also al, ace, bz)	soluble in oil (also eth, ace, chl)
reaction with base	reacts with base	does not readily react
reaction with $KMnO_4$	no reaction	no reaction

KEY:
w: soluble in water;
al: soluble in ethanol;
eth: soluble in diethyl ether;
ace: soluble in acetone;
bz: soluble in benzene;
chl: soluble in chloroform

Analysis

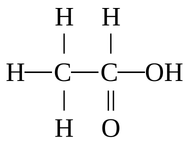
(e) Both acids contain the polar carboxyl group; in addition, stearic acid has a long hydrocarbon group with stronger van der Waals attractions than in the shorter ethanoic acid.

(f) Acetic acid is more soluble in water than is stearic acid, and less soluble in oil; stearic acid, with its long hydrocarbon component, has a longer nonpolar component and is thus more soluble in the nonpolar oil.

(g) Acetic acid reacts with sodium hydrogen carbonate, as acids do; stearic acid is not soluble in water and does not show a reaction with the aqueous sodium hydrogen carbonate.

(h) $CH_3COOH_{(aq)} + NaHCO_{3(aq)} \rightarrow CH_3COONa_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

(i) Carboxylic acids do not undergo controlled oxidation reactions; the C atom to which the OH group is attached is not bonded to an H atom to allow further oxidation of the OH group to a C=O group.



ethanoic acid

Evaluation

(j) (Sample answer) Yes, the Experimental Design allowed the collection of appropriate evidence regarding all aspects of this investigation except for the reaction with sodium hydrogen carbonate; since the stearic acid was not highly soluble in water, it is inconclusive whether it reacts with sodium hydrogen carbonate.

(k) (Sample answer) Answers obtained in the Analysis are in agreement with the Prediction.

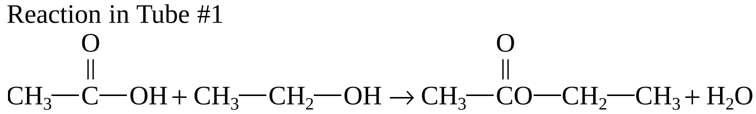
(l) (Sample answer) The theoretical model of carboxylic acids did help in the prediction of the chemical properties of these acids. The effect of the polar and nonpolar components of each acid could be used to predict physical and chemical properties of the compounds.

ACTIVITY 1.7.2 SYNTHESIS OF ESTERS

(Page 89)

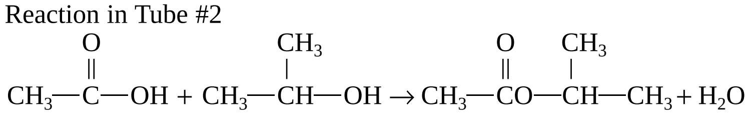
(a) Both ethanol and 2-propanol reacted with glacial acetic acid to form products with fruity odours. 1-pentanol reacted with glacial acetic acid to form a product with an odour like bananas.

(b) Reaction in Tube #1



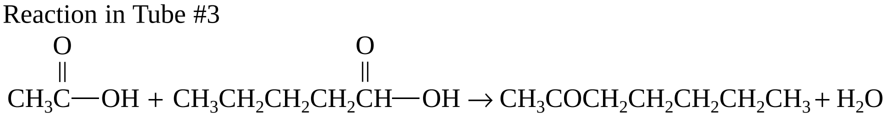
ethanoic acid ethanol ethyl ethanoate water

Reaction in Tube #2



ethanoic acid 2-propanol isopropyl ethanoate water

Reaction in Tube #3



ethanoic acid 1-pentanol isopentyl ethanoate water

(c) The concentrated sulfuric acid acts as a catalyst.

(d) The glacial acetic acid mixed with the aqueous sulfuric acid to form a homogeneous mixture; acetic acid is thus soluble in aqueous solution. This is explained by the presence of its polar carboxylic group which can hydrogen bond with water.

(e) The esters are insoluble in aqueous solution because each one formed a layer on top of the cold water in the evaporating dish. This is explained by the loss of the hydroxyl group from the carboxyl group when the ester bond is formed; thus, the ability to hydrogen bond with water is lost.