2017

Question 39 **(25 marks)**

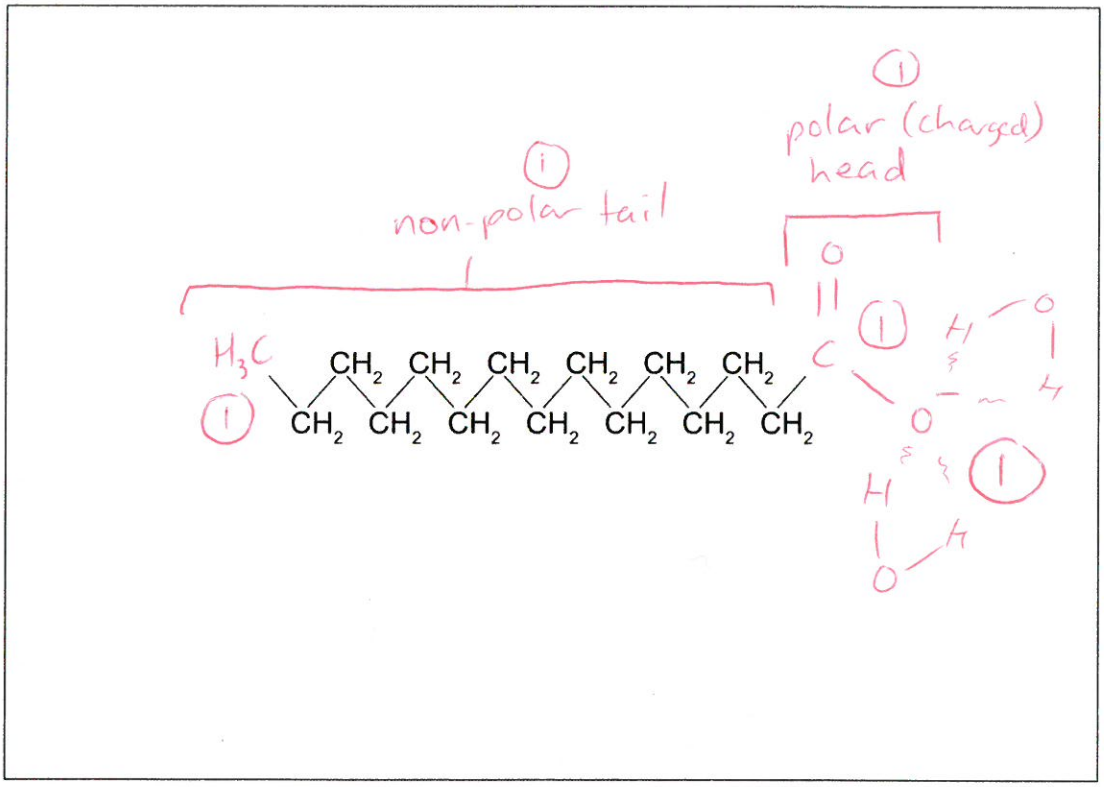
A cosmetic company advertises a range of 'inspiring quality organic, natural and essential personal care ingredients' in its skin care, hair care, aromatherapy and soaps products. It claims that the soaps it sells are made from different ingredients boasting 'an array of perfumes and cosmetic benefits'.

Soaps are a class of substances used to clean grease, dirt or oils from a surface such as skin. They do this because they are capable of dissolving in both aqueous and oily systems at the same time.

(a) (i) On the diagram below:

- complete the structure of a soap
- identify and label the key structural features of soap
- draw **two** molecules of water showing how they are orientated about soap.

(5 marks)



The process of dissolving is a consequence of attractive forces between solvent and solute. The different parts of soap are capable of producing different types of attractive forces.

(ii) Name and explain the origin of the predominant attractive force exhibited between the composite particles of soap and water. (3 marks)

- Soap and water interact by ion-dipole forces (1) between the charged carboxylate head on the soap (1) and the positive dipoles on the hydrogen atoms in water (1)

(iii) Name and explain the origin of the predominant attractive force exhibited between the composite particles of soap and oil. (3 marks)

- Soap and oil interact by dispersion forces (1) between the non-polar hydrocarbon tail of the soap (1) and the non-polar fatty acid/ hydrocarbon chains on the oils

(b) Explain why soaps do **not** function very effectively in hard water. (2 marks)

- Soaps react with ions in hard water (Ca^{2+}/Mg^{2+}/Fe^{2+}) to form an insoluble precipitate called soap scum. (1) This reduces the soaps concentration, preventing it from cleaning effectively (1)

Question 39 (continued)

Fats and oils are essentially esters of fatty acids. These esters are called 'triglycerides' and are derived from glycerol and three fatty acids.

(c) (i) Name the functional group in glycerol. (1 mark)

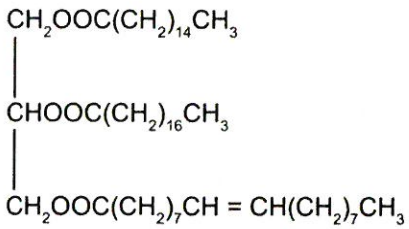
alcohol

(ii) State the **two** distinctive parts of a fatty acid used to make soap. (2 marks)

One: hydrocarbon chain

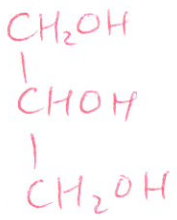
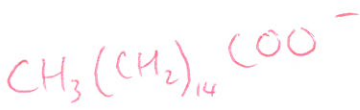
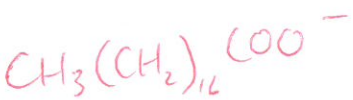
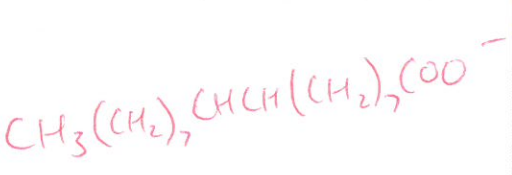
Two: carboxylic acid group

Below is a typical animal fat (triglyceride).



To produce soap, the above fat can be hydrolysed with concentrated sodium hydroxide solution.

(d) Draw structural formulae of the **four** products from this saponification process. Names are **not** required. (4 marks)

(e) Why are soap solutions basic? (2 marks)

- Soap molecules have a carboxylate group (COO^-) (1) That is a weak base/ can accept protons from water to produce OH^- ions. (1)

Under Australian law, any company wishing to make soap commercially using a saponification process must register with the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) administered by the Department of Health.

(f) State **one** health risk caused by chemicals used in the saponification process that would require careful monitoring by NICNAS. (1 mark)

- Sodium hydroxide is corrosive and can cause severe damage to eyes + skin

The following table claims to list soaps in increasing order of cleaning effectiveness.

Soaps and their chemical structure

Common name	Chemical structure
Sodium caprylate	$CH_3(CH_2)_6COONa$
Sodium caprate	$CH_3(CH_2)_8COONa$
Sodium laurate	$CH_3(CH_2)_{10}COONa$
Sodium myristate	$CH_3(CH_2)_{12}COONa$
Sodium palmitate	$CH_3(CH_2)_{14}COONa$
Sodium stearate	$CH_3(CH_2)_{16}COONa$
Sodium arachidate	$CH_3(CH_2)_{18}COONa$
Sodium behenate	$CH_3(CH_2)_{20}COONa$
Sodium lignocerate	$CH_3(CH_2)_{22}COONa$
Sodium cerotic	$CH_3(CH_2)_{24}COONa$

least effective ↓ most effective

(g) Use the information in the table to write an **hypothesis** that could be used to investigate cleaning effectiveness. (2 marks)

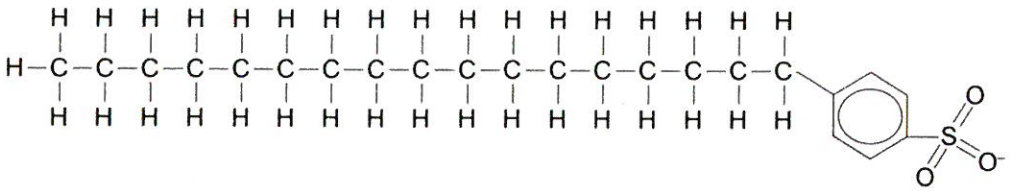
When the length of the hydrocarbon chain in a soap is increased its cleaning effectiveness will increase

IV + DV (1) proposed relationship (1)

2019

Question 37 **(24 marks)**

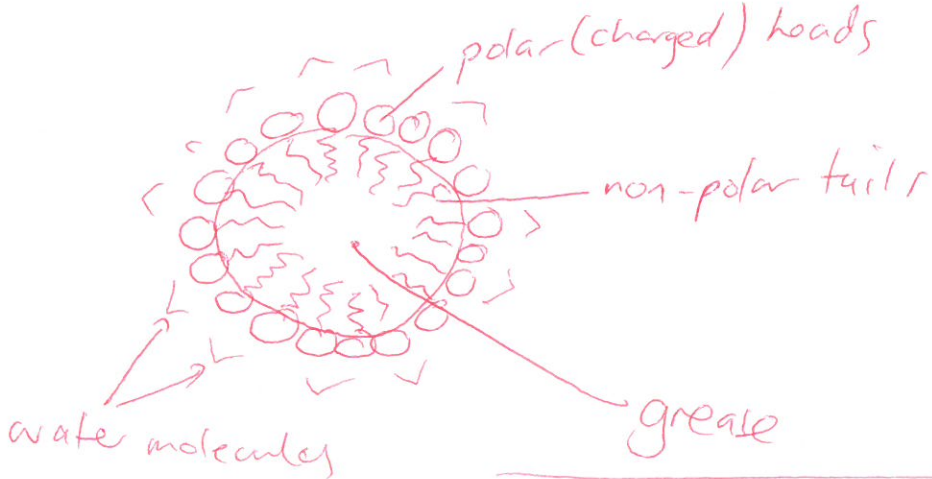
Detergents and soaps are both used as cleaning agents. The general structure of a detergent is given below.



(a) Explain how detergents are able to remove grease from a surface by referring to the intermolecular forces present. Include a labelled diagram to illustrate your answer.

(7 marks)

- The hydrocarbon chain interacts strongly with grease (1) by dispersion forces (1)
- The charged sulfonate head interacts strongly with water (1) by ion-dipole forces
- When agitated, micelles will form so that the tails of the detergent molecules are interacting with the grease, with the polar heads surrounding the structure so that it can dissolve in water (1)



tails shown in grease (1)
heads shown on outside (1)

Detergents are considered to be more versatile cleaners than soap.

(b) Explain why soaps are generally less effective than detergents as cleaning agents in hard water. Include a relevant equation in your answer. (4 marks)

- Soaps will form insoluble precipitates with ions found in hard water (Fe^{2+}, Ca^{2+}, Mg^{2+}) (1)

$$M^{2+}_{(aq)} + 2R\text{-}COO^-_{(aq)} \rightarrow M(R\text{-}COO)_{2(s)}$$ (1)

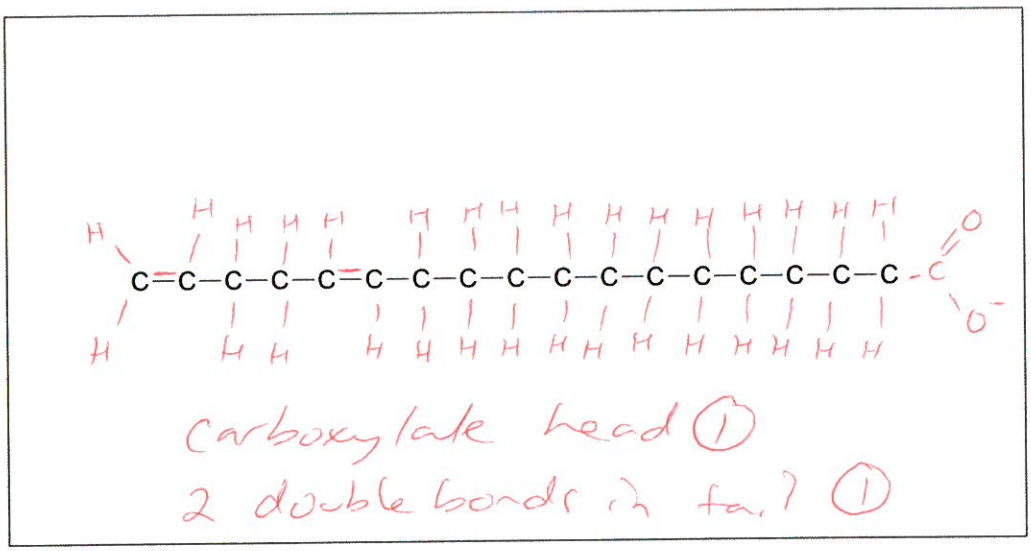
- This causes their concentration to decrease, making them ineffective (1)

- Detergents will not form insoluble precipitates with these metal ions (1)

Question 37 (continued)

Alkenes can also form soaps.

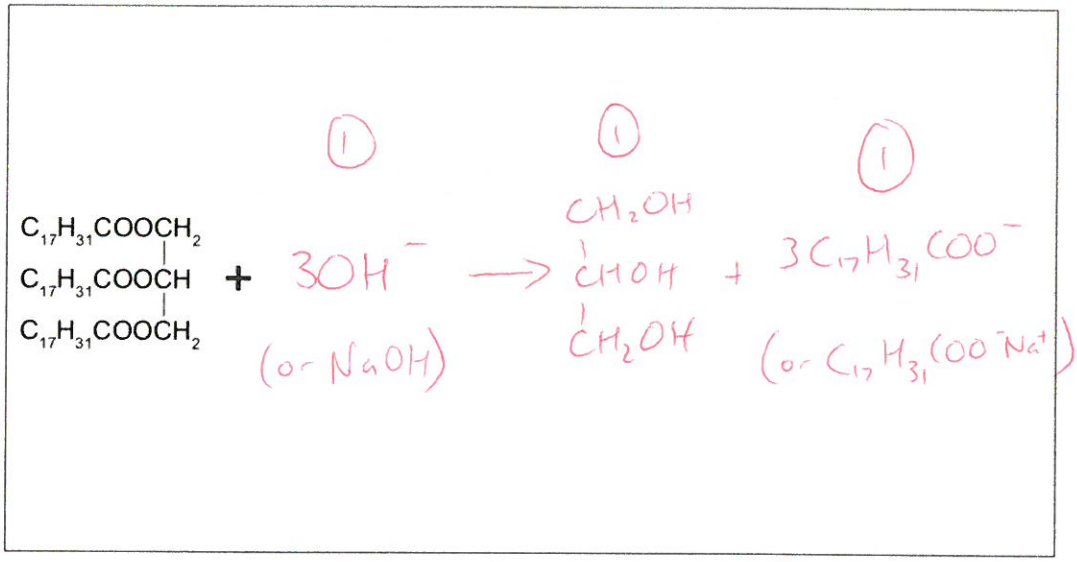
(c) Draw a structural diagram for the soap ion, $C_{17}H_{31}CO_2^-$ using the incomplete structure below. Show **all** atoms and bonds. (2 marks)



carboxylate head (1)

2 double bonds in tail (1)

(d) Write an equation showing the formation of this soap from the fat (triglyceride) shown below. (3 marks)



The formation of soap is both an endothermic and equilibrium reaction.

(e) Predict and explain the conditions that would result in the highest yield of soap in the shortest amount of time. (8 marks)

Yield

- High temperature (1)
- ↑ temp ↑ both Forward + reverse RR, due to ↑ proportion of successful collisions (↑ rate of collisions)
- but causes a greater increase in the forward rate due to its higher E_a (1)
- High concentration of reactants / high pH (1)
- High reactant concentration increases forward reaction rate without immediately affecting reverse reaction rate, causing a shift to the right / increase in yield (1)

Amount of time (eg rate)

- High temperature (1)
- Increases rate due to increased rate of collisions and increased proportion of successful collisions (1)
- High reactant concentration / high pH (1)
- Increases rate due to increased rate of collisions (1)

Note: pressure will not impact rate or yield as no reactants or product are gaseous