Organic Chemistry - Problem Sheet

1. For each of the following, identify the type of organic compound and then name it.

a)
$$CH_3CH_2CH \cdot CH_2CH \cdot CH_2CH_3$$
$$\quad\quad\;\; | \quad\quad\;\; |$$
$$\quad\quad\; OH \quad\quad CH_3$$

b)
$$CH_3CH_2CH \cdot CH_2CH$$
$$\quad\quad\; | \quad\quad\; ||$$
$$\quad\quad CH_2 \quad O$$
$$\quad\quad\; |$$
$$\quad\quad CH_3$$

c)
$$\quad\quad\quad\quad CH_3$$
$$\quad\quad\quad\quad |$$
$$CH_3-CH-C-CH_2-CH-CHO$$
$$\quad\quad | \quad | \quad\quad\quad |$$
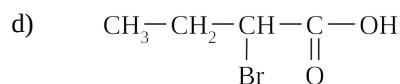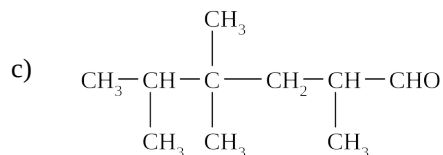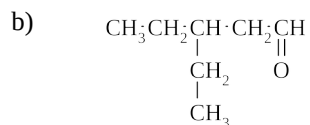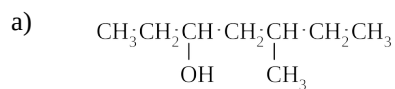$$\quad\quad CH_3 \; CH_3 \quad\quad CH_3$$

d)
$$CH_3-CH_2-CH-C-OH$$
$$\quad\quad\quad\quad | \quad ||$$
$$\quad\quad\quad\; Br \quad O$$

e)
$$CH_3CH_2CH_2CH_2CH_2CH_2CH_2C-OH$$
$$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad || $$
$$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad O$$

f)
$$CH_3CH_2CH \cdot CH_2CH_2CH_3$$
$$\quad\quad\quad\; |$$
$$\quad\quad\quad COOH$$

g)
$$CH_3-C-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$$
$$\quad\quad || $$
$$\quad\quad O$$

h)
$$CH_3CH \cdot CH_2CO \cdot CH_2$$
$$\quad\quad\; | \quad\quad\quad\quad\; |$$
$$\quad\quad CH_3 \quad\quad\quad Cl$$
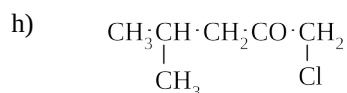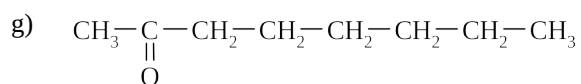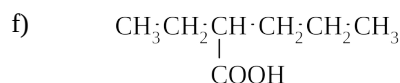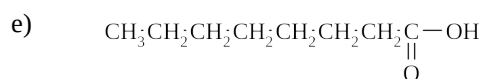
2. Draw the structural formulae of the following compounds:

a) pentanal   b) 2-methylbutan-2-ol   c) 3-bromo-3-ethylhexan-2-amine

d) 2,2-dichlorooctan-4-one   e) 4-chloro-5-methylhexanoic acid

3. Give the name and formula of the organic compound formed in each of the following reactions:

Reaction mixture	Name of product	Formula of product
a) $CH_3\,CH_2\,CH_2\,OH$ is mixed with an acidified solution of potassium permanganate for a short time, and the product is then removed from the reaction mixture by distillation.		
b) $CH_3\,CH_2\,CH_2\,CH_2\,CH_2\,OH$ is boiled with an acidified solution of potassium dichromate.		
c) hexan-3-ol is reacted with an acidified solution of sodium dichromate		
d) 2-methylbutan-2-ol is boiled with a solution of acidified potassium permanganate.		
e) $CH_3-CH-C-OH$ $\;\;\;\;\;\;\; \| \;\;\; \|$ $\;\;\;\;\; CH_3 \; O$ is heated with an acidified solution of potassium dichromate		
f) pentan-3-ol is mixed with an acidified solution of potassium permanganate and the mixture is heated.		

4. First write the two relevant half equations, then derive the overall ionic equation for each of the following reactions (use structural formulae for the organic compounds):

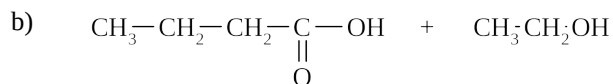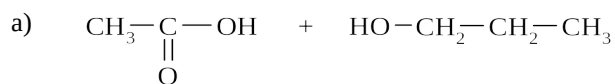a) propan-2-ol is heated with an acidified solution of potassium permanganate

b) butan-1-ol is mixed for a short time with an acidified solution of sodium dichromate

c) pentanal is heated with an acidified solution of potassium permanganate

d) 3-methylpentan-3-ol is heated with an acidified solution of potassium permanganate

e) propan-1-ol is mixed and boiled with an acidified solution of sodium dichromate

5. Give the structural formulae and names of the esters that are formed when the following carboxylic acids and alcohols react:

a) CH_3-C-OH + $HO-CH_2-CH_2-CH_3$
         $\|$
         O

b) $CH_3-CH_2-CH_2-C-OH$ + CH_3CH_2OH
                    $\|$
                    O

c) $CH_3CH_2CH_2COOH$ + CH_3OH

6.   Name the following esters:

a) $CH_3-CH_2-CH_2-CH_2-\underset{\underset{O}{||}}{C}-O-CH_2-CH_3$

b) $CH_3CH_2COO\text{-}CH_2CH_2CH_3$

c) $CH_3-CH_2-O-\underset{\underset{O}{||}}{C}-CH_2-CH_2-CH_3$

d) $CH_3-CH_2-CH_2-O-\underset{\underset{O}{||}}{C}-H$
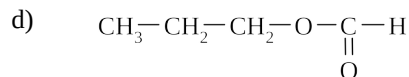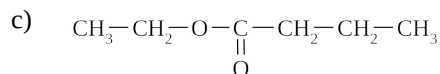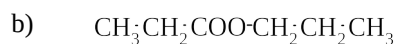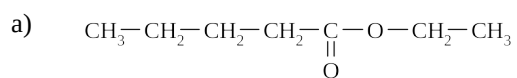
7.   Give the structural formulae of the following:

a) 1-propyl ethanoate

b) ethyl hexanoate

8.   Give the formulae of the organic compounds that are formed in the following reactions:

a) methyl ethanoate is boiled with a solution of hydrochloric acid

b) 1-propyl butanoate is heated with a solution of sodium hydroxide

9.   Give the formulae and names of the isomers with the following molecular formulae:

a) C_3H_8O

b) C_3H_6O

c) $C_3H_6O_2$

10. Draw a small portion of the polymer formed when the following alkenes polymerise:

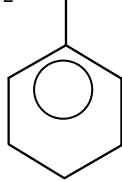a) tetrachloroethene

b) $CH_3 - CH = CH_2$
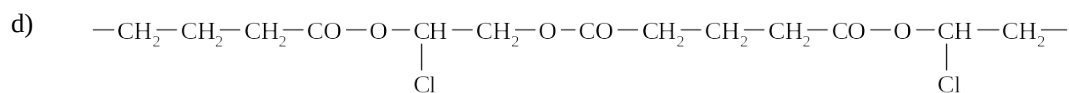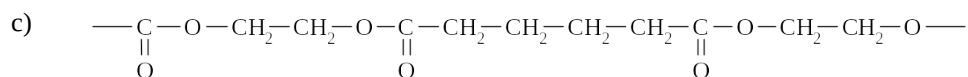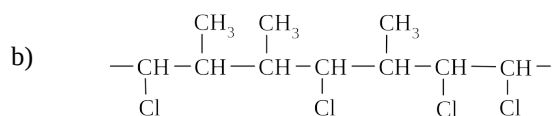
10. c) $CH_2{=}CH$ (styrene

11. Draw a small portion of the condensation polymer formed when the following monomers react:

a) $HO{-}C{-}CH_2{-}CH_2{-}C{-}OH$ + $HO{-}CH_2{-}OH$
            $\parallel$ $\parallel$
            O O
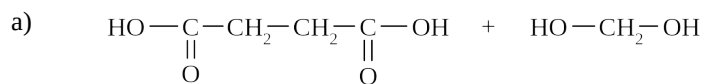
b)   propane-1,3-diol   +   pentanedioic acid

12. Give the structural formulae of the monomers used to make each of the following polymers:

a) $-CH{-}CH_2{-}CH{-}CH_2{-}CH{-}CH_2{-}CH{-}$
         $\mid$ $\mid$ $\mid$ $\mid$
         Br   Br   Br   Br

b)
         CH_3 CH_3 CH_3
          $\mid$ $\mid$ $\mid$
   $-CH{-}CH{-}CH{-}CH{-}CH{-}CH{-}CH{-}$
     $\mid$ $\mid$ $\mid$ $\mid$
     Cl   Cl   Cl   Cl

c) $-C{-}O{-}CH_2{-}CH_2{-}O{-}C{-}CH_2{-}CH_2{-}CH_2{-}CH_2{-}C{-}O{-}CH_2{-}CH_2{-}O{-}$
         $\parallel$ $\parallel$ $\parallel$
         O O O

d) $-CH_2{-}CH_2{-}CH_2{-}CO{-}O{-}CH{-}CH_2{-}O{-}CO{-}CH_2{-}CH_2{-}CH_2{-}CO{-}O{-}CH{-}CH_2{-}$
                        $\mid$ $\mid$
                        Cl   Cl
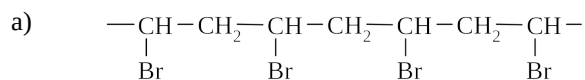
13. Identify the following as a detergent, a soap , a fatty acid, a fat or glycerol:

a) CH_2 - CH - CH_2
         $\mid$ $\mid$ $\mid$
         OH   OH OH

b)
         $CH_3 (CH_2)_n$ SO_3^- Na^+

c) $CH_3(CH_2)_{16}$ - COO - CH_2
                                                $\mid$
      $CH_3(CH_2)_{16}$ - COO - CH
                                                $\mid$
      $CH_3(CH_2)_{16}$ - COO - CH_2

d) $CH_3(CH_2)_{16}$ - COO^- Na^+

e) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2C$ - OH
                                                                            $\parallel$
                                                                            O
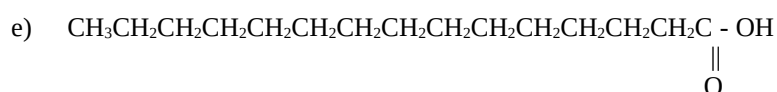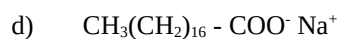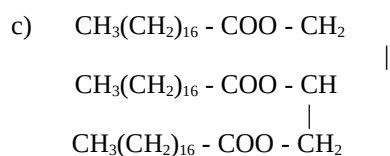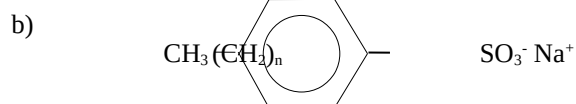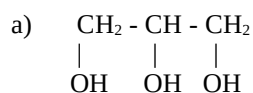
14. a) An organic compound is found to contain 92.25% carbon and 7.75% hydrogen. If the molecular mass is 78, what is   the molecular formula?

    b) In the absence of a catalyst, the compound does not react with bromine in the presence or absence of sunlight.
        Propose a structural formula for the compound.

15. A sample of a compound containing carbon, hydrogen and nitrogen only was burned in oxygen and produced 264 g
of   carbon dioxide , 63.0 g of water and 46.0 g of nitrogen dioxide.

    a) Calculate the empirical formula of the compound.

    b) If the molecular mass of the compound is approximately 95 , calculate the molecular formula of the compound.

    c) If the compound is an aromatic substance, propose a structural formula of this compound.

16. An 11.0 mg sample of an organic compound containing carbon, hydrogen and oxygen only was burned in an excess
of   oxygen and yielded 26.4 mg of CO_2 and 5.40 mg of H_2O.
      Calculate the empirical formula of the compound

TEE Questions
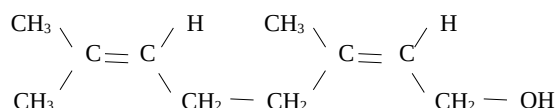
17. The following is the structural formula of the natural oil geraniol.

    Which one of the following statements about geraniol is **false**?
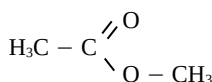
    A   *Cis/trans* isomerism can occur about each of the double bonds.
    B   It is an alcohol
    C   It will decolourise a water-solution containing potassium permanganate and sulfuric acid.
    D   It will decolourise bromine water.
    E   With controlled oxidation, the - CH_2OH group of geraniol can be converted into - COOH.

18. Only one of the following is a correct formula. Which is it?

    A $CH_3 - OH - CH_2 - CH_3$
    B $CH_3 - CH_2 = CH_2 - CH_3$
    C $CH_3 - CH_3 - CH - CO - C(CH_3)_3$
    D $CH_3 - CH_2 - NH_2 - CH = CH_2$
    E $(CH_3)_2CH_2$

19. Which one of the following compounds can be oxidised to form a ketone?

    A CH_3OH B CH_3CH_2OH C $CH_3CH_2CH_2OH$

    D $CH_3CH_2CHOHCH_3$ E $(CH_3)_3COH$

20. The following is part of the structure of a polymer.

    Draw a structural formula for each of the monomers needed to produce the polymer.

21. A pure substance 'A' is a colourless liquid which boils at 57°C and has a strong odour. 'A' burns readily in air leaving no ash, and qualitative analysis shows that nitrogen, sulfur, and the halogens are absent. It may thus be concluded that 'A' contains the elements carbon and hydrogen and possibly oxygen.

    a) In an experiment, 0.6047 g of 'A' is burnt in a current of dry air, and 1.078 g of carbon dioxide and 0.441 g of water are produced. Calculate the empirical formula of 'A'.

    b) At 100°C and 1.00 atm pressure, 0.1367 g of 'A' evaporates to occupy a volume of 57 mL. Calculate the molecular weight of 'A'.

    c) What is the molecular formula of 'A'?

    d) A nuclear magnetic resonance spectrum of 'A' indicates that all the H atoms in 'A' are in methyl groups. Draw the structural formula for 'A'.

22. Many compounds have the empirical formula C_3H_6O. Draw the structural formulae for a ketone, an aldehyde, a carboxylic acid and an ester which have this empirical formula. Name each compound.

	Structure	Name
A ketone		
An aldehyde		
A carboxylic acid		
An ester		

23. Draw a structural formula for a section of the polymer that is made from the monomer vinyl chloride (chloroethene), CH_2CHCl. The section must contain at least 6 carbon atoms. All bonds must be shown.
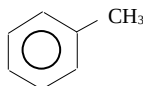
24. A pure substance 'A' is a white solid, melting at 153°C, which is found by qualitative analysis to contain carbon and hydrogen. With no simple test for oxygen available, it can be assumed oxygen might be present.
When 0.8062 g of 'A' is burnt in a current of dry oxygen, 1.110 g of carbon dioxide and 0.303 g of water are produced.
Calculate the empirical formula of 'A'.

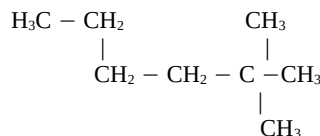25. Which one of the following is the formula of an aromatic compound?

A
$H_3C - C$ $\diagup^O_{O - CH_3}$

B CH_3

C

D

E $H_3C - CH_2$ CH_3
          $|$ $|$
          $CH_2 - CH_2 - C - CH_3$
                          $|$
                          CH_3

26. Which one of the following substances can be made from just the materials listed?

	Substance	*Starting materials*
A	propyl ethanoate	propanoic acid, ethanol, and concentrated sulfuric acid
B	propanal	propanoic acid, potassium permanganate, and dilute sulfuric acid
C	polyvinyl chloride	dichloroethane and a catalyst
D	soap	concentrated sodium hydroxide solution and glycerol
E	ethanoic acid	ethanal, sodium dichromate, and dilute sulfuric acid

27. Write equations for any reactions that occur in the following procedures.
In each case describe in full what you would observe, including any
        * colours   * odours   * precipitates (give the colour)
        * gases evolved (give the colour or describe as colourless)
If a reaction occurs but the change is not visible, you should state this.

    a) A little concentrated sulfuric acid is added to a mixture of methanol and acetic acid (ethanoic acid) and the mixture is heated.

    b) Dilute hydrochloric acid is added to sodium acetate (sodium ethanoate) solution.

28. Identify by name or formula an example of each of the following.

    a) A diprotic acid

    b) A colourless redox primary standard

    c) An aromatic acid

    d) A negatively charged complex ion

29.   Stearate ion is present in soapy water, and has the following structure

$$CH_3(CH_2)_{16} - C \overset{O}{\underset{O^-}{<}}$$
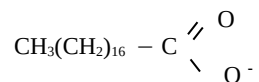
Draw the structural formula for the organic species that is produced when 1 mol L^{-1} HCl is added to the soap solution.

30.   Work out the equation for the reaction that occurs when propan-2-ol is warmed with water-solution containing potassium dichromate and sulfuric acid.

|	
Oxidation half-equation	
Reduction half-equation	
Redox equation	

31.   For each of the following pairs of compounds, describe a chemical test to distinguish between them. Give all the steps, but equations are not required.

	Your chemical test. Describe fully	What you would observe in each case
$Cu(NO_3)_2$ and $CuSO_4$		with $Cu(NO_3)_2$
		with $CuSO_4$
$MgCl_2$ and $ZnCl_2$		with $MgCl_2$
		with $ZnCl_2$
CH_3CH_2OH and CH_3COOH		with CH_3CH_2OH
		with CH_3COOH

32.   Work out the equation for the reaction that occurs when ethanal (acetaldehyde) is warmed with water-solution containing potassium dichromate and sulfuric acid.
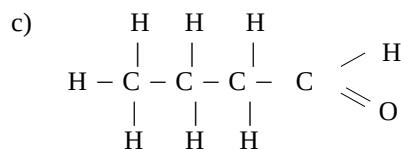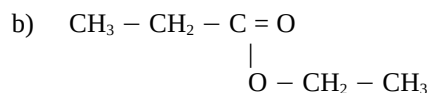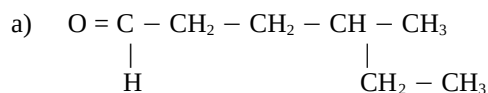
Oxidation half-equation	
Reduction half-equation	
Redox equation	

33.   One or more of the following compounds can be used industrially to produce a polymer.

COOH

COOH

$CH_3CH_2 - OH$ $HO - CH_2CH_2 - OH$

COOH
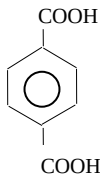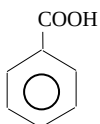
Draw a structural formula showing part of this polymer, including in your diagram as least four monomer units.

34. Write the systematic (IUPAC) name of each of the following:

a) $O = C - CH_2 - CH_2 - CH - CH_3$

         | |

        H $CH_2 - CH_3$

b) $CH_3 - CH_2 - C = O$

                     |

                   $O - CH_2 - CH_3$

c)
H   H   H
| | | H
H − C − C − C − C
| | | O
H   H   H

d)
H   H   H
| | |
H − C − C − C − O   O
| | | C
H   H   H |
                   H
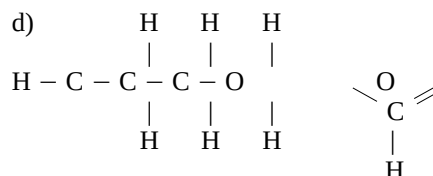
35. The following diagram shows part of a polymer molecule

$- O - CH_2CH_2 - O - C - CH_2CH_2 - C - O - CH_2CH_2 - O - C - CH_2CH_2 -$

                         ‖   ‖   ‖

                         O   O   O
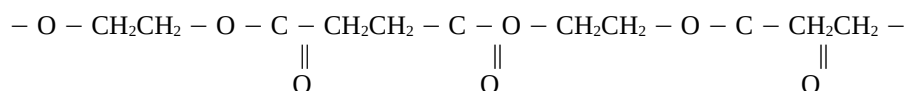
a) Draw structural formula for the two monomer molecules which combine to form the polymer.

b) Name the type of polymerisation process involved.

c) Give the formula of the substance which is produced in the polymerisation, besides the polymer.

36. a) A pure compound, which is a colourless liquid at room temperature, boils at 138°C, and analysis shows it to contain 90.49% carbon and 9.48% hydrogen by mass. Calculate the empirical formula of the compound.

b) Explain why the empirical formula calculated in a) cannot be its molecular formula.

c) A known mass of the liquid is vaporised, and from the volume of gas produced the molecular weight of the compound is calculated to be about 105. What is the molecular formula of the compound.

d) The odour of the liquid, and the smoky flame when a sample is burned, indicates that the compound is aromatic.   Draw one of the four possible structural formulae for the compound.

37. Which one of the following is an esterification reaction?

A $CH_3CH_2CH_3 + Br_2 \rightarrow CH_3CH_2CH_2Br + HBr$
B $CH_3COOH + CH_3OH \rightarrow CH_3COOCH_3 + H_2O$
C $CH_3CHCH_2 + HBr \rightarrow CH_3CH_2CH_2Br$
D $CH_3COOCH_3 + OH^- \rightarrow CH_3COO^- + CH_3OH$
E $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

38. Which two of the following substances are commonly used in the manufacture of soap?

    I   A long chain fatty acid   II   A natural oil
    III   Sodium hydroxide   IV   Stearic acid

A   I and II   B   I and III   C   II and III
D   II and IV   E   III and IV

39. Which of the following could be used for cleaning purposes?

    I $CHCl_3$ II   A water solution of NH_3 III   A water solution of $CH_3(CH_2)_{16}COONa$

A   I only   B   II only   C   III only
D   I and II only   E   All of them

40. Examine this section of the structure of an addition polymer.

$$\begin{array}{ccccc} CH_3 & CH_3 & Cl & CH_3 & CH_3 \\ | & | & | & | & | \\ -C-CH_2-C-CH_2-C-CH_2-CH_2 & & -C-CH_2-C- \\ | & | & | & | & | \\ Cl & Cl & CH_3 & Cl & Cl \end{array}$$
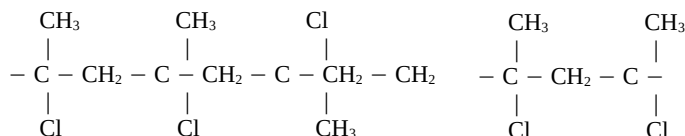
Which one of the following compounds could polymerise to form this chain?

A $CH_3 - C = CH_2$
            |
            Cl

B $CH_3 - CH = CH$
              |
              Cl

C $CH_2 = CH - CH_2$
                  |
                  Cl

D $CH_2 = C - CH = CH$
          | |
          Cl   Cl

E $CH_2 = C - CH = CH_2$
             |
             Cl
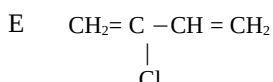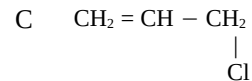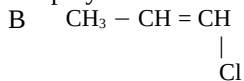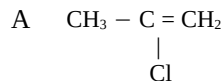
41. Which one of the following is the correct classification of the molecule depicted here?
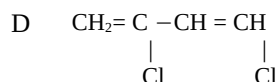
$$\begin{array}{c} HO-C-CH_2-CH_2-O-C-CH_3 \\ \quad\; || \qquad\qquad\qquad\qquad || \\ \quad\; O \qquad\qquad\qquad\qquad\; O \end{array}$$
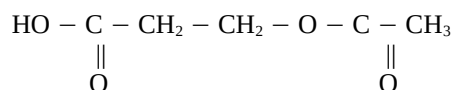
A   Alcohol and aldehyde   B   Alcohol and ketone
C Carboxylic acid and ketone   D   Carboxylic acid and ester
E Dicarboxylic acid

42.
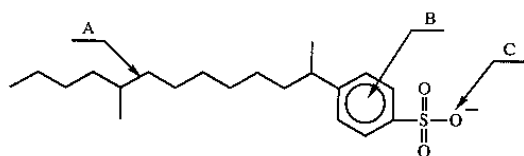
a) Which of the labelled arrows (A, B, C) on the diagram above indicates

    i) the part of the ion where delocalised electrons may be found

    ii) a hydrophobic group

    III) a hydrophilic group?

b) i) What common substances contain such an ion?

    ii) In one or two sentences, state how the properties of this ion relate to its use.

43. An unknown organic compound Q is known to be a simple carboxylic acid.
Its molecular weight is known to be 74.

a) Draw a complete structural formula for the compound Q including all hydrogen atoms.

   Give the IUPAC name.

b) Draw the structure of an ester which is isomeric with the unknown compound Q.

   Give the IUPAC name for the ester.

44. Substance A has the empirical formula C_2H_4O and is immiscible with water. When A is heated with 6 mol L^{-1} sodium hydroxide solution, two substances B and C are produced. When C is treated with an acidified solution of potassium permanganate, a monoprotic acid D is formed. When D is neutralised with sodium hydroxide solution, more substance B is produced. If the molecular weight of B is 82, write the names of substances A, B, C and D.

Substance A: Substance B:

Substance C: Substance D:

ANSWERS

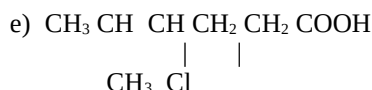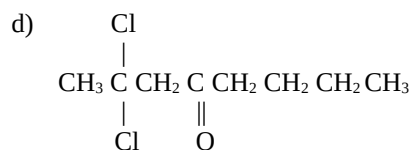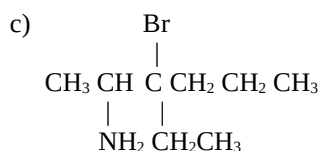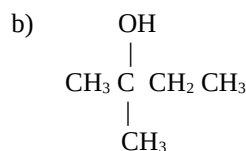1. a) alcohol,   5-methylheptan-3-ol
   b) aldehyde, 3-ethylpentanal
   c) aldehyde. 2,4,4,5-tetramethylhexanal
   d) carboxylic acid, 2-bromobutanoic acid
   e) carboxylic acid, octanoic acid
   f) carboxylic acid, 2-ethylpentanoic acid
   g) ketone, octan-2-one
   h) ketone, 1-chloro-4-methylpentan-2-one

2. a) $CH_3\ CH_2\ CH_2\ CH_2\ CHO$

   b)
   $$\begin{array}{c} OH \\ | \\ CH_3\ \underset{|}{C}\ CH_2\ CH_3 \\ CH_3 \end{array}$$

   c)
   $$\begin{array}{c} Br \\ | \\ CH_3\ CH\ \underset{|}{C}\ CH_2\ CH_2\ CH_3 \\ NH_2\ CH_2CH_3 \end{array}$$

   d)
   $$\begin{array}{c} Cl \\ | \\ CH_3\ \underset{|}{C}\ CH_2\ \underset{\|}{C}\ CH_2\ CH_2\ CH_2\ CH_3 \\ Cl \qquad O \end{array}$$

   e) $CH_3\ \underset{\underset{CH_3}{|}}{CH}\ \underset{\underset{Cl}{|}}{CH}\ CH_2\ CH_2\ COOH$

3. a) propanal $CH_3\ CH_2\ CHO$
   b) pentanoic acid $CH_3\ CH_2\ CH_2\ CH_2\ COOH$
   c) hexan-3-one $CH_3\ CH_2\ \underset{\|}{C}\ CH_2\ CH_2\ CH_3$
         O
   d) no reaction

   e) methylpropanoic acid $CH_3 - \underset{\underset{CH_3}{|}}{CH} - \underset{\|}{C} - OH$
                O

   f) pentan-3-one $CH_3\ CH_2\ \underset{\|}{C}\ CH_2\ CH_3$
                O

4. a)
   $$\begin{array}{l} \underset{\underset{CH_3\ CH\ CH_3}{|}}{OH} \quad\rightarrow\quad \underset{\underset{CH_3\ C\ CH_3}{\|}}{O} + 2H^+ + 2e \qquad x\ 5 \\ MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O \qquad\qquad x\ 2 \end{array}$$
   $$5\ CH_3\ \underset{\underset{OH}{|}}{CH}\ CH_3 + 2MnO_4^- + 6H^+ \rightarrow 5\ CH_3\ \underset{\underset{O}{\|}}{C}\ CH_3 + 2\ Mn^{2+} + 8\ H_2O$$

   b)
   $$\begin{array}{l} CH_3\ CH_2\ CH_2\ CH_2\ OH \rightarrow CH_3\ CH_2\ CH_2\ CHO + 2H^+ + 2e \qquad x\ 3 \\ Cr_2O_7^{2-} + 14H^+ + 6e \rightarrow 2Cr^{3+} + 7\ H_2O \end{array}$$
   $$3\ CH_3\ CH_2\ CH_2\ CH_2\ OH + Cr_2O_7^{2-} + 8H^+ \rightarrow 3\ CH_3\ CH_2\ CH_2\ CHO + 2Cr^{3+} + 7\ H_2O$$

   c)
   $$\begin{array}{l} CH_3\ CH_2\ CH_2\ CH_2\ CHO + H_2O \rightarrow CH_3\ CH_2\ CH_2\ CH_2\ COOH + 2H^+ + 2e \qquad x\ 5 \\ MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O \qquad\qquad x\ 2 \end{array}$$
   $$5\ CH_3\ CH_2\ CH_2\ CH_2\ CHO + 2MnO_4^- + 6H^+ \rightarrow 5\ CH_3\ CH_2\ CH_2\ CH_2\ COOH + 2\ Mn^{2+} + 3\ H_2O$$

   d) no reaction

   e)
   $$\begin{array}{l} CH_3\ CH_2\ CH_2OH + H_2O \rightarrow CH_3\ CH_2\ COOH + 4H^+ + 4e \qquad x\ 3 \\ Cr_2O_7^{2-} + 14H^+ + 6e \rightarrow 2Cr^{3+} + 7\ H_2O \qquad x\ 2 \end{array}$$
   $$3\ CH_3\ CH_2\ CH_2OH + 2\ Cr_2O_7^{2-} + 16H^+ \rightarrow 3\ CH_3\ CH_2\ COOH + 4Cr^{3+} + 11\ H_2O$$

5. a) $CH_3 - \underset{\underset{O}{\|}}{C} - O - CH_2 - CH_2 - CH_3$ 1-propyl ethanoate

   b) $CH_3 - CH_2 – CH_2 - \underset{\underset{O}{\|}}{C} - O - CH_2\ CH_3$ ethyl butanoate
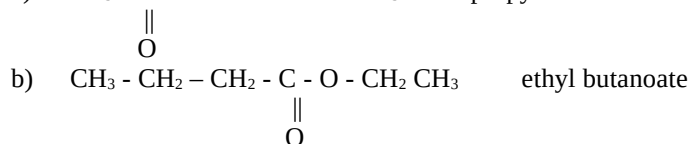
5(cont) c) $CH_3 \, CH_2 \, CH_2 \, COO \, CH_3$ methyl butanoate

6. a) ethyl pentanoate   b) 1-propyl propanoate   c) ethyl butanoate   d) 1-propyl methanoate

7. a) CH_3 - C - O - CH_2 - CH_2 - CH_3 b) $CH_3 \, CH_2 \, CH_2 \, CH_2 \, CH_2$ C - O - $CH_2 \, CH_3$
$\qquad \qquad$ ‖ $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ ‖
$\qquad \qquad$ O $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ O

8. a) $CH_3 \, COOH$ + CH_3OH b) CH_3 - CH_2 - CH_2 - COO^- Na^+ + CH_3 - CH_2 - CH_2OH

9. a) $CH_3 \, CH_2 \, CH_2 \, OH$ $CH_3 \, CH \, CH_3$ $CH_3 \, O \, CH_2 \, CH_3$

$\qquad$ propan-1-ol $\qquad\qquad\qquad$ | $\qquad\qquad\qquad\qquad$ (an ether)
$\qquad\qquad\qquad\qquad\qquad\qquad\quad$ OH
$\qquad\qquad\qquad\qquad\qquad\quad$ propan-2-ol

  b) $CH_3 \, CH_2 \, CH$ $\qquad\qquad\qquad$ $CH_3 \, C \, CH_3$ $\qquad\qquad$ CH_2 — CH_2
$\qquad\qquad\quad$ ‖ $\qquad\qquad\qquad\qquad\qquad\quad$ ‖ $\qquad\qquad\qquad$ \ /
$\qquad\qquad\quad$ O $\qquad\qquad\qquad\qquad\qquad\quad$ O $\qquad\qquad\qquad\qquad$ CH - OH
$\qquad$ propanal $\qquad\qquad\qquad\qquad$ propanone $\qquad\qquad$ cyclopropanol

$\qquad$ $CH_2 = CH \, CH_2 \, OH$ $\qquad\qquad$ $CH_2 = C \, CH_3$ $\qquad\qquad$ $CH = CH \, CH_3$
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ | $\qquad\qquad\qquad\qquad\qquad$ |
$\qquad$ 1-hydroxyprop-3-ene $\qquad\qquad\qquad$ OH $\qquad\qquad\qquad\qquad$ OH
$\qquad$ (or prop-3-ene-1-ol) $\qquad\qquad$ 2-hydroxyprop-1-ene $\qquad$ 1-hydroxyprop-1-ene
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad$ (or prop-1-ene-2-ol) $\qquad$ (or prop-1-ene-1-ol)

  c) $CH_3 \, CH_2 \, C \, OH$ $\qquad\qquad\qquad$ $CH_3 \, C \, O \, CH_3$ $\qquad$ H C O $CH_2 \, CH_3$
$\qquad\qquad\qquad$ ‖ $\qquad\qquad\qquad\qquad\qquad\quad$ ‖ $\qquad\qquad\qquad$ ‖
$\qquad\qquad\qquad$ O $\qquad\qquad\qquad\qquad\qquad\quad$ O $\qquad\qquad\qquad$ O
$\qquad$ propanoic acid $\qquad\qquad\qquad$ methyl ethanoate $\qquad\quad$ ethyl methanoate

$\qquad$ Also, a series of compounds with - one double bond and two alcohol groups
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ - a three membered ring and two alcohol groups
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ - one alcohol group and an aldehyde or ketone group

 10. a) - CCl_2 - CCl_2 - CCl_2 - CCl_2 - CCl_2 - CCl_2 -

  b) $\quad CH_3 \qquad\quad CH_3 \qquad\quad CH_3$
$\qquad$ | $\qquad\qquad\quad$ | $\qquad\qquad\quad$ |
$\quad$ - CH - CH_2 - CH - CH_2 - CH - CH_2 -

  c) $\quad$ - CH_2 - CH - CH_2 - CH - CH_2 - CH - CH_2 - CH -
$\qquad\qquad\qquad$ | $\qquad\qquad\qquad$ | $\qquad\qquad\qquad$ | $\qquad\qquad\quad$ |

11. a) - C - CH_2 - CH_2 - C - O - CH_2 - O - C - CH_2 - CH_2 - C - O - CH_2 - O
$\qquad\quad$ ‖ $\qquad\qquad\qquad\quad$ ‖ $\qquad\qquad\qquad\quad$ ‖ $\qquad\qquad\qquad\quad$ ‖
$\qquad\quad$ O $\qquad\qquad\qquad\quad$ O $\qquad\qquad\qquad\quad$ O $\qquad\qquad\qquad\quad$ O

  b) $\quad$ - O - CH_2 - CH_2 - CH_2 - O - C - CH_2 - CH_2 - CH_2 - C -
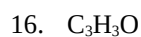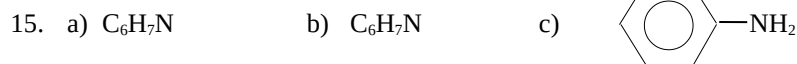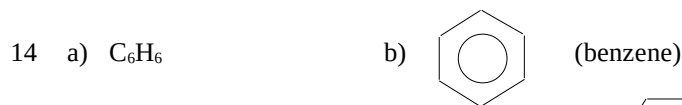$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ ‖ $\qquad\qquad\qquad\qquad\qquad$ ‖
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ O $\qquad\qquad\qquad\qquad\qquad$ O

12. a) $\quad CH = CH_2$ $\qquad\qquad\qquad\qquad\qquad$ b) $\quad CH_3$
$\qquad\qquad$ | $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ |
$\qquad\qquad$ Br $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ CH = CHCl

  c) $\quad$ HO - CH_2 - CH_2 - OH $\qquad$ HO - C - CH_2 - CH_2 - CH_2 - CH_2 - C - OH
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad$ ‖ $\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ ‖
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad$ O $\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ O

12 (cont) d)   HO - CH - CH$_2$ - OH   HOOC - CH$_2$ - CH$_2$ - CH$_2$ - COOH
$\qquad\qquad$ |
$\qquad\qquad$ Cl
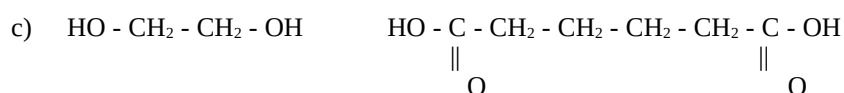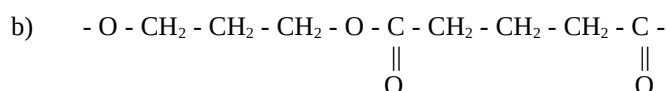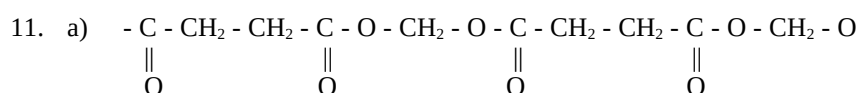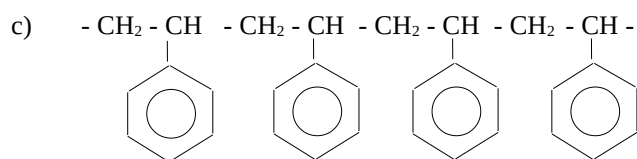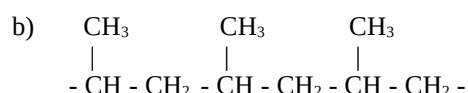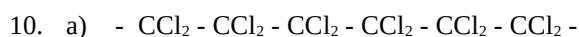
13. a)   glycerol   b) detergent   c)   fat   d)   soap   e)   fatty acid

14 a) C$_6$H$_6$ b)   (benzene)

15. a) C$_6$H$_7$N   b) C$_6$H$_7$N   c)   —NH$_2$

16. C$_3$H$_3$O

17. A   18.   E   19.   D

20.
$\qquad$ H$\quad$ H$\quad$ H
$\qquad$ |$\qquad$|$\qquad$|$\qquad\qquad\qquad$ O$\qquad\qquad\qquad$ O
$\qquad$ |$\qquad$|$\qquad$|$\qquad\qquad\qquad$ ||$\qquad\qquad\qquad$ ||
HO − C − C $\quad$− C− OH$\qquad$ HO − C −$\bigcirc$ − C − OH
$\qquad$ |$\qquad$|$\qquad$|
$\qquad$ H$\quad$ H$\quad$ H
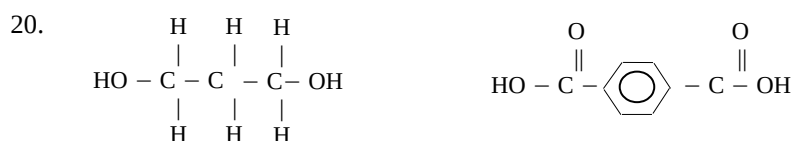
21. a) moles of CO$_2$ = 1.078/44.01 = 0.02449 = moles of C in 'A'
$\qquad$ moles of H$_2$O = 0.441/18.016 = 0.02448   so, moles of H in 'A' = 2 x 0.02448 = 0.0490
$\qquad$ mass of C present = 0.02449 x 12.01 = 0.2941 g   mass of H present = 1.008 x 0.0490 = 0.04939 g
$\qquad$ mass of O present = 0.6047 - (0.2941 + 0.04939) = 0.2612 g
$\qquad$ mole of O present in 'A' = 0.2612/16.0 = 0.01632
$\qquad$ moles ratio = C : H : O = 0.02449 : 0.0490 : 0.01632 = 1.50 : 3.00 : 1   = 3 : 6 : 2
$\qquad$ i.e. the **empirical formula is C$_3$H$_6$O$_2$**

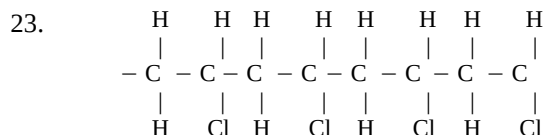$\quad$ b) PV = nRT   n =   = 0.001862
$\qquad$ molar mass = 0.1367/0.001863 = 73.38 g mol^{-1} i.e. **molecular weight = 73.4**

$\quad$ c) molecular formula = n x empirical formula   i.e. n = 73.4/74   ≈ 1
$\qquad$ so **molecular formula = C$_3$H$_6$O$_2$**

$\quad$ d)   CH$_3$ − C − O − CH$_3$
$\qquad\qquad\qquad$ ||
$\qquad\qquad\qquad$ O
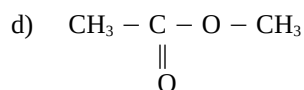
22.

	Structure	Name
A ketone	CH$_3$ − C − CH$_3$ $\qquad$ || $\qquad$ O	propanone
An aldehyde	CH$_3$ − CH$_2$ − CH $\qquad\qquad$ || $\qquad\qquad$ O	propanal
A carboxylic acid	CH$_3$ − CH$_2$ − CH$_2$ − CH$_2$ − CH$_2$ − C− OH $\qquad\qquad\qquad\qquad\qquad$ || $\qquad\qquad\qquad\qquad\qquad$ O	hexanoic acid
An ester	CH$_3$ − CH$_2$ − CH$_2$ − CH$_2$ − C − O − CH$_3$ $\qquad\qquad\qquad\qquad$ || $\qquad\qquad\qquad\qquad$ O	methyl pentanoate

23.
$\qquad$ H$\qquad$ H$\quad$ H$\qquad$ H$\quad$ H$\qquad$ H$\quad$ H$\qquad$ H
$\qquad$ |$\qquad$|$\quad$|$\qquad$|$\quad$|$\qquad$|$\quad$|$\qquad$|
$\quad$ − C $\:$− C − C $\:$− C − C $\:$ − C − C $\:$− C
$\qquad$ |$\qquad$|$\quad$|$\qquad$|$\quad$|$\qquad$|$\quad$|$\qquad$|
$\qquad$ H$\quad$ Cl$\:$ H$\qquad$ Cl$\:$ H$\qquad$ Cl$\:$ H$\qquad$ Cl

24. moles of CO_2 = 1.110/44.01 = 0.02522 = moles of C in 'A'
     moles of H_2O = 0.303/18.016 = 0.01682   so, moles of H in 'A' = 2 x 0.01682 = 0.03364
     mass of C present = 0.02522 x 12.01 = 0.3029 g   mass of H present = 1.008 x 0.03364 = 0.03391 g
     mass of O present = 0.8062 - (0.3029 + 0.03391) = 0.4694 g
     mole of O present in 'A' = 0.4695/16.0 = 0.02934
     moles ratio = C : H : O = 0.02522 : 0.03364 : 0.02934 = 1 : 1.33 : 1.16 = 6 : 7.98 : 6.983
                                                                  ≈ 6 : 8 : 7

   i.e. the **empirical formula is $C_6H_8O_7$**

25. B   26. E

27. a) $CH_3COOH(l) + CH_3OH(l) \rightarrow CH_3COOCH_3(l) + H_2O(l)$ - sweet smelling odour produced, mixture remains
                                                                   colourless

    b) $CH_3COO^-(aq) + H^+(aq) \rightarrow CH_3COOH(aq)$ - solution remains colourless, vinegar-smelling odour produced.

28. a) sulfuric acid   b) oxalic acid   c) benzoic acid
    d) tetrahydroxozincate ion

29. $CH_3(CH_2)_{16} - C \begin{smallmatrix} \nearrow O \\ \searrow OH \end{smallmatrix}$
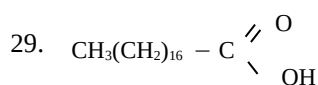
30.

Oxidation half-equation	$CH_3CHOHCH_3 \rightarrow CH_3COCH_3 + 2H^+ + 2e$
Reduction half-equation	$Cr_2O_7^{2-} + 14H^+ + 6e \rightarrow 2Cr^{3+} + 7H_2O$
Redox equation	$Cr_2O_7^{2-} + 8H^+ + 3CH_3CHOHCH_3 \rightarrow 2Cr^{3+} + 7H_2O + 3CH_3COCH_3$

31.

	Your chemical test. Describe fully	What you would observe in each case
$Cu(NO_3)_2$ and $CuSO_4$	Dissolve both in water, add a solution of barium nitrate to each	with $Cu(NO_3)_2$ - no precipitate forms
		with $CuSO_4$ - precipitate forms
$MgCl_2$ and $ZnCl_2$	Dissolve both in water, then slowly add a solution of sodium hydroxide to each	with $MgCl_2$ - a white precipitate forms
		with $ZnCl_2$ - a white precipitate forms, but it then dissolves when excess NaOH is added.
CH_3CH_2OH and CH_3COOH	Test both with moist blue litmus paper	with CH_3CH_2OH - litmus not affected
		with CH_3COOH - litmus turns red

32.

Oxidation half-equation	$CH_3CHO + H_2O \rightarrow CH_3COOH + 2H^+ + 2e$
Reduction half-equation	$Cr_2O_7^{2-} + 14H^+ + 6e \rightarrow 2Cr^{3+} + 7H_2O$
Redox equation	$Cr_2O_7^{2-} + 8H^+ + 3CH_3CHO \rightarrow 2Cr^{3+} + 4H_2O + 3CH_3COOH$

33.
$$- O - \overset{O}{\overset{\|}{C}} - \langle \bigcirc \rangle - \overset{O}{\overset{\|}{C}} - O - CH_2 - CH_2 \qquad - O - \overset{O}{\overset{\|}{C}} - \langle \bigcirc \rangle - \overset{O}{\overset{\|}{C}} - O - CH_2 - CH_2 -$$
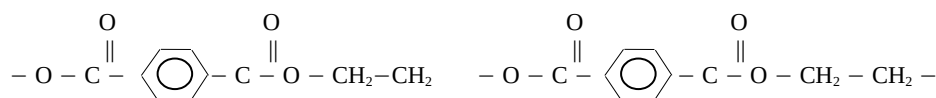
34. a) 4-methylhexanal   b) ethyl propanoate   c) butanal   d) 1-propyl methanoate

35. a) $HO - CH_2CH_2 - OH$ $HO - C - CH_2CH_2 - C - OH$
                                                                $\|$ $\|$
                                                                O   O
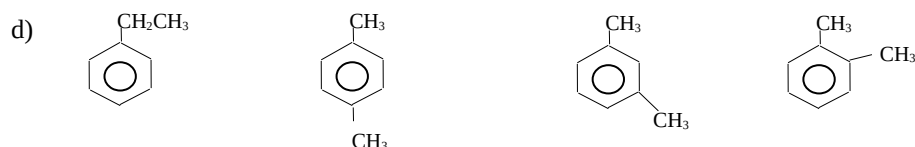
   b) condensation   c) H_2O

36. a)   C : H = 90.49/12.01 : 9.48/1.008   =   7.53 : 9.40   =   1 : 1.25   =   4 : 5
       i.e. the **empirical formula is C_4H_5**

   b) Hydrocarbons have an even number of hydrogens (or there would be an uneven number of electrons in this molecule)

36. c) molecular formula = n x empirical formula   i.e. n = 105/53 $\approx$ 2
       so **molecular formula = C_8H_{10}**

   d)

37.   B   38.   C   39.   E

40.   A   41.   D

42.   a) i) B   ii) A   iii) C
      b) i) detergents

      ii) When a detergent is added to washing water, the surfactant molecules surround the grease and oil with the non-polar "tails" attached to the grease, and the polar ends left exposed to the water. With agitation, small grease blobs surrounded by detergent ions are produced. These blobs are able to mix, and possibly dissolve in the water because they act as polar substances (due to the polar ends of the ions projecting from them). Thus, the grease can be rinsed away.

43.   a) It is a carboxylic acid containing 3 C atoms i.e.

          name: propanoic acid

      b)

          name: methyl ethanoate
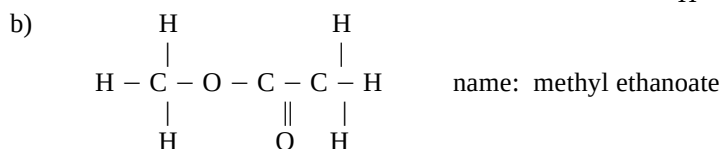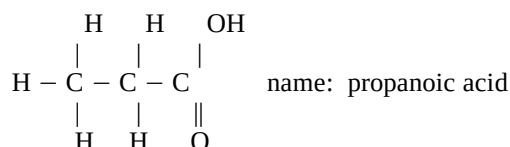
44.   Substance A: ethyl ethanoate   Substance B: sodium ethanoate

         Substance C: ethanol   Substance D: ethanoic acid