Questions

Module 7: Organic Chemistry

Multiple-choice questions: 1 mark each

1. Butan-1-ol burns in oxygen according to the following equation.

$$C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

How many moles of carbon dioxide would form if two moles of butan-1-ol were burnt in excess oxygen?

(A) 2

(B) 4

(C) 8

(D) 10

2013 HSC Q4

2. The table shows the enthalpy of for four compounds.

Compound	*Enthalpy of combustion ($kJ\ mol^{-1}$)*
CO	233
CH_4	890
C_2H_2	1300
C_2H_6	1560

Which of these compounds would produce the greatest amount of energy if 1.00 g of each is burnt?

(A) CO

(B) CH_4

(C) C_2H_2

(D) C_2H_6

Adapted 2013 HSC Q11

3. Which of the following industrial processes is used to produce ethanol from ethylene?

(A) Hydration

(B) Dehydration

(C) Addition polymerisation

(D) Condensation polymerisation

2011 HSC Q1

4. Which of the following shows two products that result from the fermentation of glucose?

(A) Cellulose and water

(B) Ethanol and oxygen

(C) Carbon dioxide and water

(D) Ethanol and carbon dioxide

2011 HSC Q2

5. Which property would be most useful in distinguishing between butan-1-ol and propan-1-ol?

(A) Boiling point

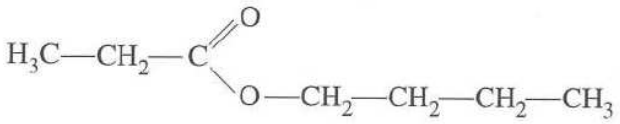
(B) Colour

(C) Conductivity

(D) Density

2011 HSC Q6

6. What is the systematic name of the molecule shown?



(A) Butyl butanoate

(B) Propyl butanoate

(C) Butyl propanoate

(D) Propyl propanoate

2011 HSC Q8

7. $C_2H_4 \rightarrow$ X $\rightarrow$ polymer

Which of the following compounds is represented by X in the flowchart?

(A) Cellulose

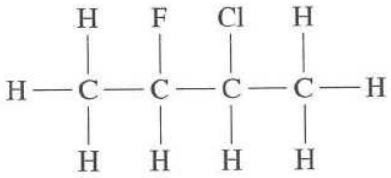
(B) Ethanol

(C) Glucose

(D) Styrene

2012 HSC Q2

8. What is the correct IUPAC name for the following compound?



(A) 2-chloro-3-fluorobutane

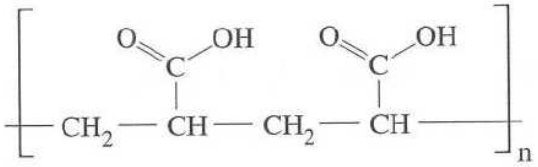
(B) 2-fluoro-3-chlorobutane

(C) 3-fluoro-2-chlorobutane

(D) 3-chloro-2-fluorobutane

Adapted 2012 HSC Q12

9. A portion of a resin made from acrylic acid (CH_2=CHCOOH) is shown.



Which type of reaction results in the formation of this polymer?

(A) Addition

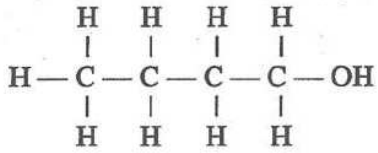
(B) Condensation

(C) Dehydration

(D) Esterification

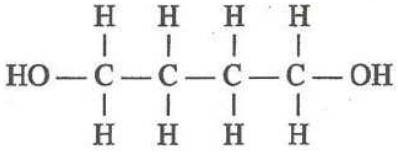
2013 HSC Q9

10. The structural formula of 1–butanol is given below

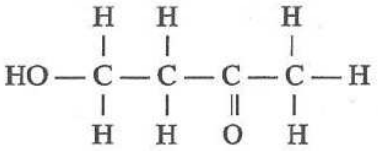


An isomer of this compound is

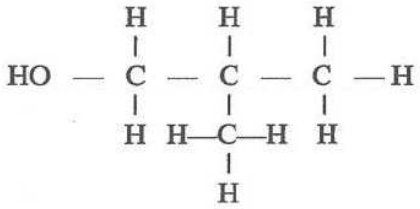
(A)



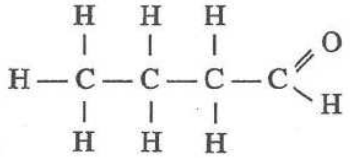
(B)



(C)



(D)



11. Which of the following is a balanced equation representing the fermentation of glucose?

(A) $C_6H_{12}O_6(aq) \rightarrow 2C_3H_6O_3(aq)$

(B) $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

(C) $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

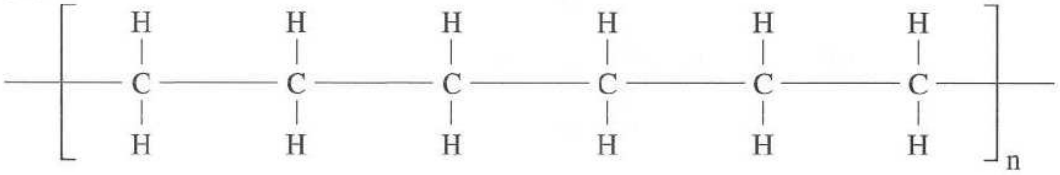
(D) $C_6H_{12}O_6(aq) + 3O_2(g) \rightarrow C_2H_5OH(aq) + 4CO_2(g) + 3H_2O(l)$

2012 HSC Q5

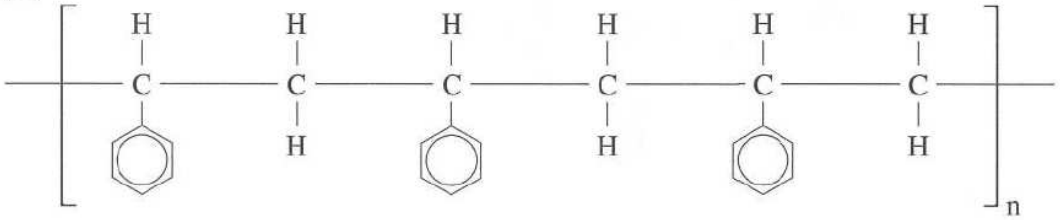
12.

What is the structure of the polymer most likely to have been used in the manufacture of the cup shown?

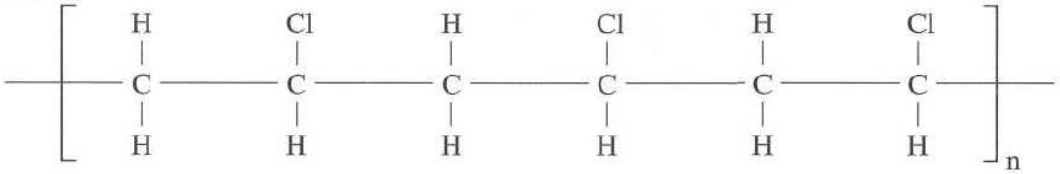
(A)



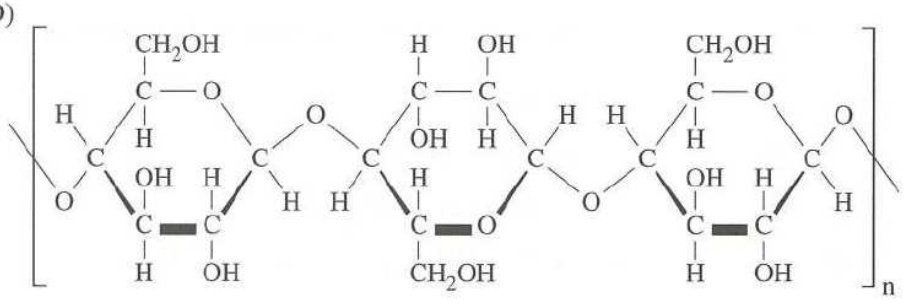
(B)



(C)



(D)



2013 HSC Q13

13. The enthalpy of combustion of propan-1-ol is 2021 kJ mol^{-1}. Combustion takes place according to the equation:

$$2C_3H_7OH(l) + 9O_2(g) \rightarrow 6CO_2(g) + 8H_2O(l)$$

What mass of water is formed when 1530 kJ of energy is released?

(A) 3.4 g

(B) 14 g

(C) 55 g

(D) 144 g

Adapted 2012 HSC Q17

14. Which of these substances can be oxidised to produce propanoic acid?

(A) 2-propanol

(B) propanone

(C) 1-butanol

(D) 1-butene

2000 HSC Q13

15. 2-Butanol is heated under reflux with acidified potassium dichromate solution.

What is the major organic product?

(A) butanal

(B) butyl butanoate

(C) butanone

(D) butanoic acid

1999 HSC Q9

16. Which of these groups of organic substances is listed in decreasing order for melting and boiling points?

(A) Ethanol, ethanoic acid, fluroethane, ethane

(B) Ethanoic acid, ethanol, fluoroethane, ethane

(C) Ethanoic acid, ethanol, ethane, fluoroethane

(D) Ethane, fluroethane, ethanol, ethanoic acid

17. Which compound can form when bromine water reacts with propene?

(A) 1-bromopropane

(B) 2-bromopropane

(C) 1,1-dibromopropane

(D) 1,2-dibromopropane *2011 HSC Q11*

18. How many isomers are there for C_3H_6BrCl?

(A) 3

(B) 4

(C) 5

(D) 6 *2011 HSC Q14*

19. The enthalpy of combusion of pentan-1-ol is 2800 kJ mol^{-1}. A quantity of pentan-1-ol was combusted, generating 108 kJ of heat.

What mass of pentan-1-ol was combusted?

(A) 2.29 g

(B) 2.86 g

(C) 3.32 g

(D) 3.40 g *Adapted 2011 HSC Q17*

20. What is the specific heat of a compound?

(A) The quantity of heat required to boil 1 g of the compound

(B) The quantity of heat required to melt 1 g of the compound

(C) The quantity of heat required to increase the temperature of the compound by 1°C

(D) The quantity of heat required to increase the temperature of 1 g of the compound by 1°C *2008 HSC Q6*

21. Ethene may be converted into poly(ethene). What type of reaction is this?

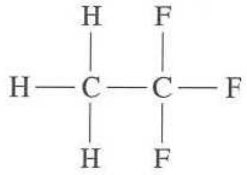
(A) Condensation

(B) Hydrolysis

(C) Oxidation/reduction

(D) Polymerisation *2001 HSC Q1*

22. The diagram shows the structural formula of a gas with the molecular formula $C_2H_3F_3$.



How many isomers are there with this molecular formula?

(A) 1

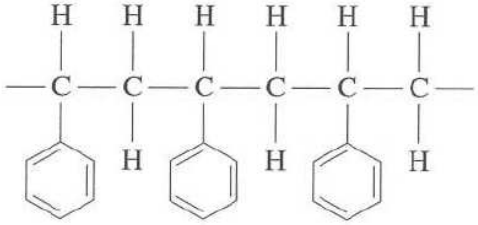
(B) 2

(C) 3

(D) 4

Adapted 2010 HSC Q4

23. The diagram shows a section of a polymer.



What is the systematic name of the monomer?

(A) Polybenzene

(B) Benzylethene

(C) Ethylbenzene

(D) Ethenylbenzene

2010 HSC Q6

24. The molar enthalpy of combustion of ethanol is 1367 kJ mol^{-1}.

What quantity of ethanol must be combusted to raise the temperature of 1.0 kg water from 50°C to boiling point at sea level (assuming no loss of heat to the surroundings)?

(A) 6.5 g

(B) 7.0 g

(C) 209 g

(D) 300 g

2008 HSC Q10

25. Water is released during a polymerisation reaction.

Which monomer is likely to have been involved in the reaction?

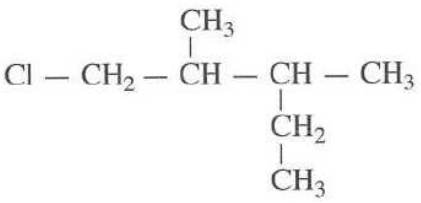
(A) Ethene

(B) Glucose

(C) Styrene

(D) Vinyl chloride *2010 HSC Q1*

26. What is the IUPAC systematic name for the compound whose structure is given below?



(A) 1-chloro-2,3-dimethylbutane

(B) 1-chloro-2-methyl-3-ethylbutane

(C) 1-chloro-2-ethyl-3-methylpentane

(D) 1-chloro-2,3-dimethylpentane *1998 HSC Q12*

27. A student completed an experiment to determine the amount of energy absorbed by a volume of water.

The following data were recorded.

Mass of beaker	215.6 g
Mass of beaker plus water	336.1 g
Final temperature of water	71.0°C
Energy absorbed	21.2 kJ

What was the initial temperature of the water?

(A) 15°C

(B) 25°C

(C) 29°C

(D) 42°C *2010 HSC Q17*

28. An organic liquid, when reacted with concentrated sulfuric acid, produces a compound that decolourises bromine water.

What is the formula of the organic liquid?

(A) C_6H_{12}

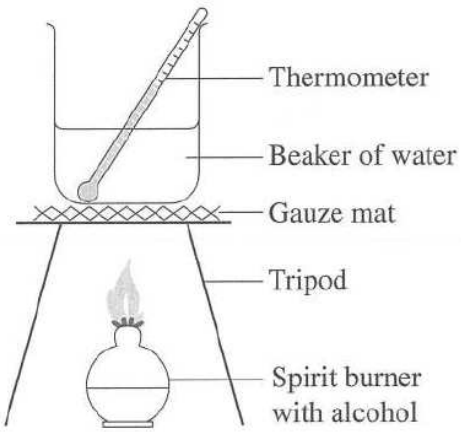
(B) C_6H_{14}

(C) $C_6H_{11}OH$

(D) $C_5H_{11}COOH$

2010 HSC Q11

29. The apparatus shown is used in a first-hand investigation to determine and compare the heat of combustion of three different liquid alkanols.



Which is the independent variable?

(A) Type of alcohol used

(B) Amount of water used

(C) Amount of alcohol used

(D) Temperature change in the water

Adapted 2009 HSC Q5

30. Why is ethanol used in preference to water as the main ingredient of perfume?

(A) Ethanol is cheaper to produce.

(B) Ethanol has no detectable odour.

(C) Ethanol dissolves esters more readily.

(D) Ethanol has a significantly lower density.

2008 HSC Q5

31. Bromine, Br_2, dissolves in unsaturated hydrocarbons and reacts immediately.

Which of the following is the best description of this process?

(A) Bromine is polar and reacts by adding bromine atoms across the double bond.

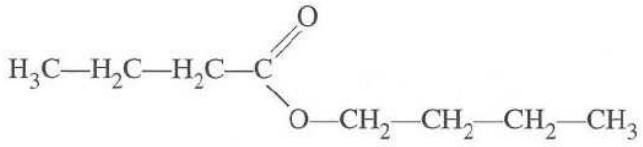
(B) Bromine is polar and reacts by substituting hydrogen atoms with bromine atoms.

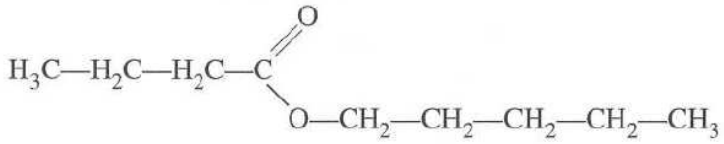
(C) Bromine is non-polar and reacts by substituting hydrogen atoms with bromine atoms.

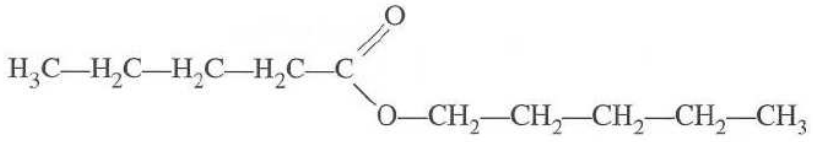
(D) Bromine is non-polar and reacts by adding bromine atoms across the double bond.

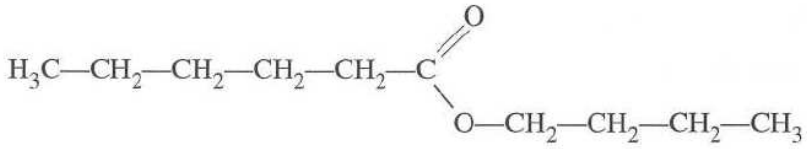
2009 HSC Q6

32. Which of the following is the main organic product resulting from the reaction of butanoic acid and pentanol?

(A) 

(B) 

(C) 

(D) 

2009 HSC Q10

33. What mass of ethanol is obtained when 5.68 g of carbon dioxide is produced during fermentation, at 25°C and 100 kPa?

(A) 2.95 g

(B) 5.95 g

(C) 33.6 g

(D) 147.2 g

2010 HSC Q15

34. In a fermentation experiment 6.50 g of glucose was completely converted to ethanol and carbon dioxide.

What is the mass of carbon dioxide produced?

(A) 1.59 g

(B) 3.18 g

(C) 9.53 g

(D) 13.0 g

2009 HSC Q13

35. In which of the following alternatives are the three compounds listed in order of increasing boiling point?

(A) Pentane, butan-1-ol, propanoic acid

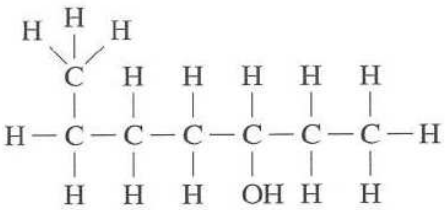
(B) Propanoic acid, butan-1-ol, pentane

(C) Propanoic acid, pentane, butan-1-ol

(D) Butan-1-ol, propanoic acid, pentane

2008 HSC Q11

36. What is the IUPAC name for the following compound?



(A) Hexan-3-ol

(B) Hexan-4-ol

(C) Heptan-3-ol

(D) Heptan-5-ol

2007 HSC Q4

37. How many isomers are there for $C_3H_6Cl_2$?

(A) 3

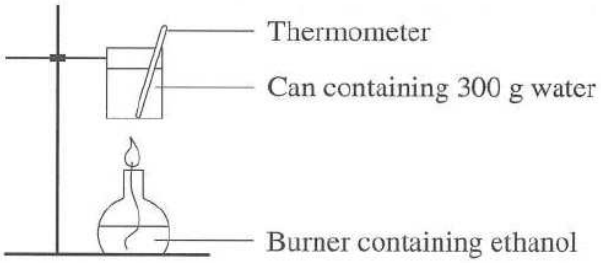
(B) 4

(C) 5

(D) 6

2006 HSC Q5

38. A student used the apparatus shown to determine the molar enthalpy of combustion of ethanol.



The following results were obtained.

Initial mass of burner	133.20 g
Final mass of burner	132.05 g
Initial temperature of water	25.0°C
Final temperature of water	45.5°C

What is the molar enthalpy of combustion calculated from this data?

(A) 22.4 kJ mol^{-1}

(B) 25.7 kJ mol^{-1}

(C) 1030 kJ mol^{-1}

(D) 1180 kJ mol^{-1}

Adapted 2006 HSC Q4

39. The enthalpy of combustion of butan-1-ol is 2676 kJ mol^{-1}.

What is the value of the enthalpy of combustion in kJ g^{-1}?

(A) 30.41

(B) 36.10

(C) 44.60

(D) 47.79

Adapted 2005 HSC Q3

40. Which of these groups of carbon compounds is listed in order of increasing boiling points?

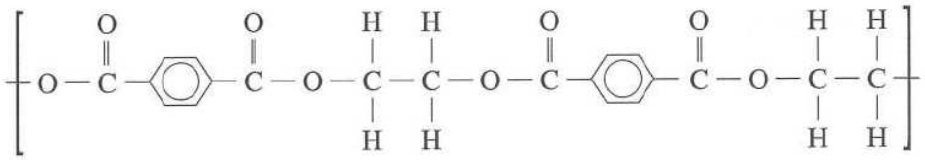
(A) Ethanol, ethane, butanol, butane

(B) Ethane, ethanol, butane, butanol

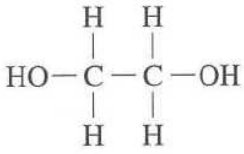
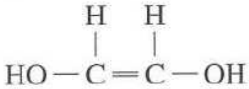
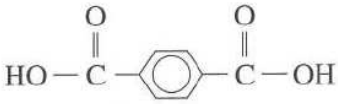
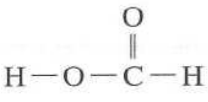
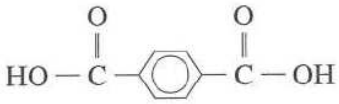
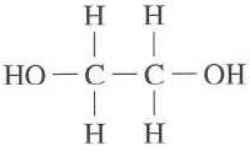
(C) Ethane, butane, ethanol, butanol

(D) Butanol, ethanol, ethane, butane

41. Terylene (polyester) is a condensation polymer. Part of the structure of the polymer is shown.

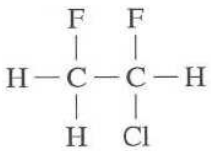


What are the two monomers that form this polymer?

	Monomer 1	*Monomer 2*
(A)		
(B)		
(C)		
(D)		

2005 HSC Q4

42. What is the name of the following compound?



(A) 1,2-difluoro-1-chloroethane

(B) 1,2-difluoro-2-chloroethane

(C) 1-chloro-1,2-difluoroethane

(D) 2-chloro-1,2-difluoroethane

2005 HSC Q13

43. Ethanol can be reacted with ethanoic acid to produce ethyl ethanoate. What type of reaction is this?

(A) Esterification

(B) Hydration

(C) Polymerisation

(D) Reduction

2004 HSC Q1

44. The table gives the enthalpy of combustion in kJ mol^{-1} for a number of different fuels.

Fuel	*Enthalpy of combustion ($kJ\ g^{-1}$)*
Methanol	22.7
Ethanol	29.6
Propanol	33.6
Petrol (octane)	47.8

The enthalpy of combustion in kJ mol^{-1} for one of the fuels was calculated as 2016 kJ mol^{-1}.

What was the fuel?

(A) Methanol

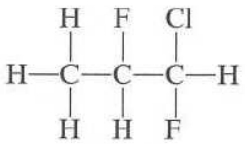
(B) Ethanol

(C) Propanol

(D) Petrol

Adapted 2003 HSC Q6

45. What is the name of the compound shown?



(A) 1-chloro-1,2-difluoropropane

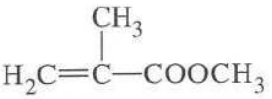
(B) 3-chloro-2,3-difluoropropane

(C) 1,2-difluoro-1-chloropropane

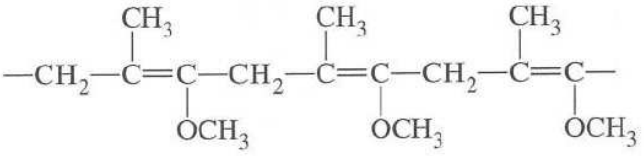
(D) 1-chloro-1,2-difluoropentane

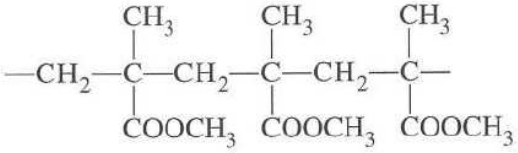
2003 HSC Q9

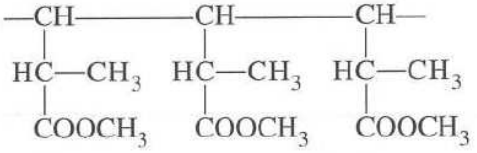
46. Which polymer is made by the polymerisation of methyl methacrylate?

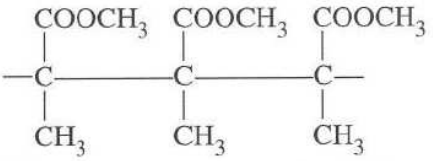


methyl methacrylate

(A) 

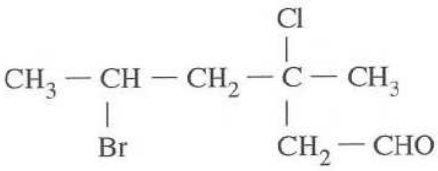
(B) 

(C) 

(D) 

2003 HSC Q11

47. The IUPAC systematic name for the compound whose structure is given below is



(A) 2-bromo-4-chloro-hexanal.

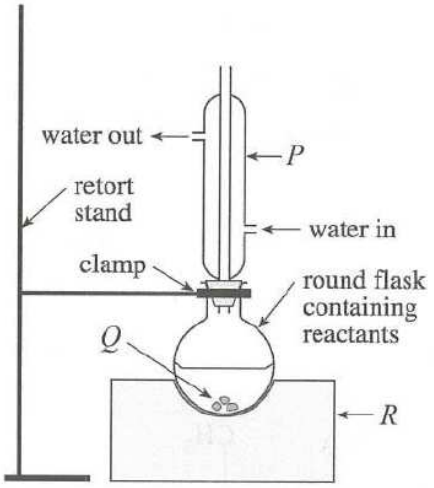
(B) 3-chloro-3-methyl-5-bromohexanal.

(C) 5-bromo-3-chloro-3-methylhexanal.

(D) 2-bromo-4-chloro-4-methylhexanal.

1997 HSC Q1

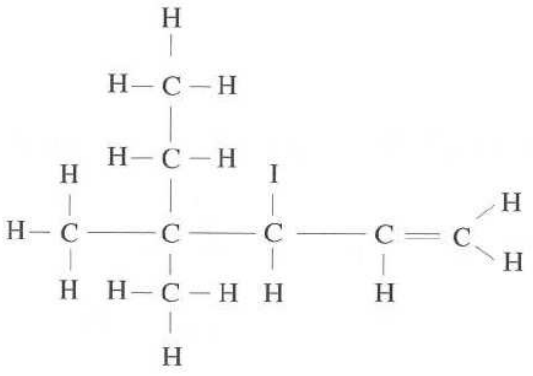
48. The diagram below shows the equipment used to prepare an ester in a school laboratory.



Identify the apparatus (*P*, *Q* and *R*) shown in the diagram.

	P	*Q*	*R*
(A)	condenser	boiling chips	heating jacket
(B)	pipette	pebbles	heating jacket
(C)	burette	boiling chips	Bunsen burner
(D)	condenser	blue metal	hotplate

49. The IUPAC systematic name for the compound whose structure is given below is



(A) 2-ethyl-3-iodo-2-methyl-4-pentene.

(B) 4-ethyl-3-iodo-4-methyl-1-pentene.

(C) 3-iodo-4,4-dimethyl-1-hexene.

(D) 4-dimethyl-3-iodo-1-hexene. *1996 HSC Q5*

50. The following list of steps refers to an experimental plan for making an ester in a flask. Some of the steps in the list may NOT be required for this experiment. The steps are NOT in the correct sequence.

1. Heat the mixture under reflux.
2. Add three drops of concentrated sulfuric acid.
3. Add 1 mL of ethanol.
4. Add 1 mL of ethene.
5. Add 1 mL of ethanoic acid.
6. Distil the mixture.
7. Add three drops of phenolphthalein indicator.

Which alternative is the best sequence for making an ester?

(A) 3, 5, 7, 1

(B) 4, 3, 7, 6

(C) 5, 4, 2, 6

(D) 5, 3, 2, 1

2002 HSC Q9

51. A condensation reaction in which an ester is formed is known as an esterification reaction. Which of these equations represents esterification?

(A) $CH_3—O—\overset{\overset{O}{\|}}{C}—CH_3 + H_2O \xrightarrow{H^+} CH_3—OH + CH_3—\overset{\overset{O}{\|}}{C}—OH$

(B) $CH_3—O—\overset{\overset{O}{\|}}{C}—H + NaOH \longrightarrow H—\overset{\overset{O}{\|}}{C}—ONa + CH_3—OH$

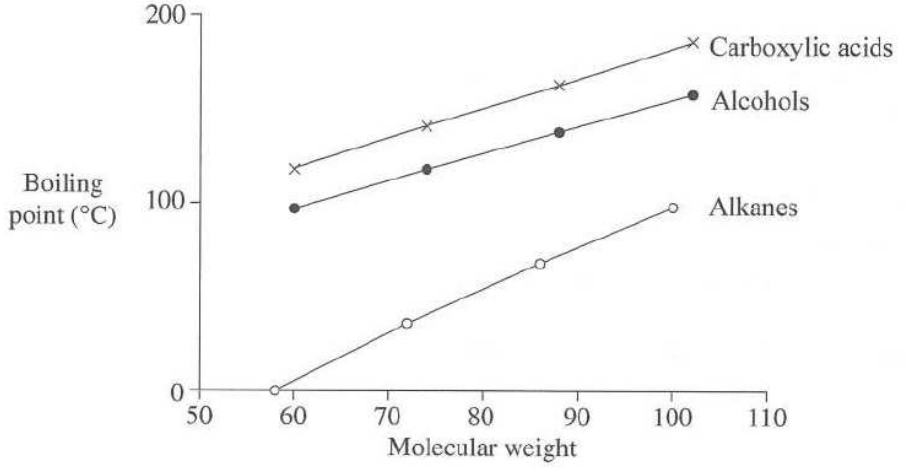
(C) $CH_3—OH + CH_3—\overset{\overset{O}{\|}}{C}—OH \xrightarrow{H^+} CH_3—CH_2—O—\overset{\overset{O}{\|}}{C}—H + H_2O$

(D) $CH_3—OH + CH_3—\overset{\overset{O}{\|}}{C}—OH \xrightarrow{H^+} CH_3—O—\overset{\overset{O}{\|}}{C}—CH_3 + H_2O$

Adapted 2002 HSC Q10

Refer to the following information to answer Questions 52 and 53.

The graph below shows some boiling points for carboxylic acids, alcohols and alkanes.



New questions 52 & 53 – using adapted graph from 2003 HSC Q25

52. Which of these statements correctly describes a trend shown in this graph?

(A) The boiling points of each group increase with increasing molecular mass due to increasing carbon chain length.

(B) The boiling points of each group increase as molecular mass increases due to there being less dispersion forces between the molecules.

(C) The boiling points of each group increase with molecular mass as less energy is needed to separate the molecules.

(D) The boiling points of each group decrease with increasing molecular mass due to increasing carbon chain length.

53. Which of these statements correctly describes the difference in the boiling points (BP) for carboxylic acids, alcohols and alkanes?

(A) Alkanes have the lowest BP due to strong H bonding.

(B) Carboxylic acids have the highest BP due to both H bonding and =O bonds.

(C) Alcohols have higher BP than alkanes due the H bonding in alkanes.

(D) Only carboxylic acids have dispersion forces and so have the highest BP.

54. Which of the following solutions has the lowest pH?

(A) 0·1M ethanoic (acetic) acid.

(B) 0·1M hydrochloric acid.

(C) 0·2M sodium hydroxide.

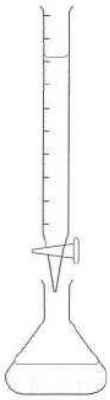
(D) 0·2M nitric acid.

1995 HSC Q2

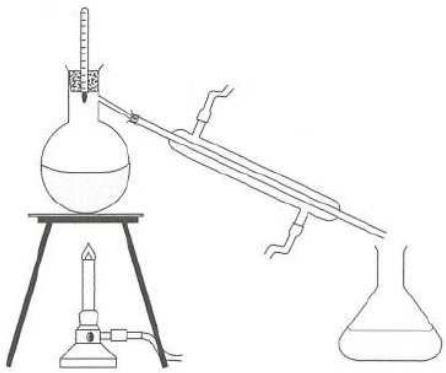
55. In a laboratory experiment, a student prepares an ester by refluxing an acid and an alcohol for thirty minutes. After this time, it is necessary to separate the product from the reaction mixture.

The correct apparatus for carrying out this separation is:

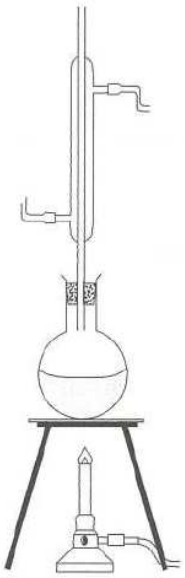
(A)



(B)



(C)



(D)

1996 HSC Q15

56. The dehydration of an alcohol produces an alkene and water.

What is the catalyst for the conversion of ethanol to ethene?

(A) NaOH

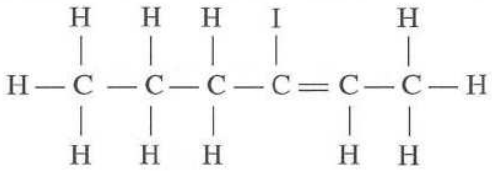
(B) H_2SO_4

(C) HNO_3

(D) Pt

Adapted 2002 HSC Q2

57. What is the IUPAC name for the compound whose structure is given below?



(A) 4-iodo-4-hexene

(B) 3-iodo-2-hexene

(C) 4-iodo-5-hexene

(D) 2-iodo-2-hexene

1999 HSC Q3

58. Chlorine reacts with butene to form 1,2-dichlorobutane. This type of reaction is called

(A) addition.

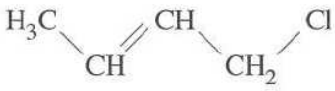
(B) oxidation.

(C) hydrolysis.

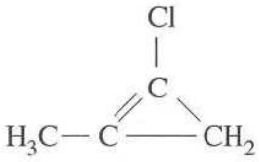
(D) substitution.

1995 HSC Q1

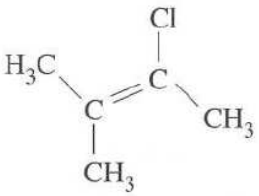
59. Which of the following formulae represent a pair of isomers?



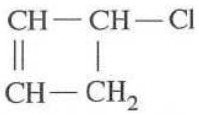
(I)



(II)



(III)



(A) (I) and (II).

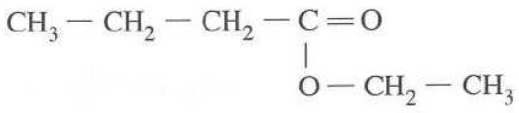
(B) (I) and (III).

(C) (I) and (IV).

(D) (II) and (IV).

1997 HSC Q12

60. The formula for an ester with a strawberry fragrance is given below.



The alcohol and carboxylic acid used to make this ester were

(A) propanol and propanoic acid.

(B) ethanol and butanoic acid.

(C) butanol and ethanoic acid.

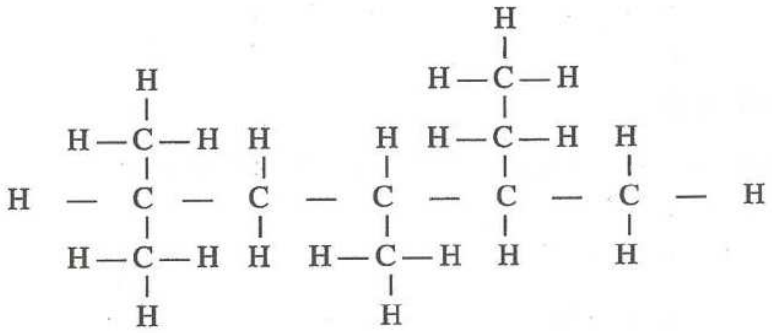
(D) butanol and butanoic acid. *Adapted 1997 HSC Q15*

61. The presence of a strong oxidising agent, such as acidified permanganate ion, is required for an alcohol to undergo oxidation.

Which entry in the table below correctly lists the product formed when that type of alcohol is oxidised under standard conditions?

	Primary alcohol	*Secondary alcohol*	*Tertiary alcohol*
(A)	Aldehyde	Ketone	Ester
(B)	Ketone	Aldehyde	No reaction
(C)	Carboxylic acid	Ketone	No reaction
(D)	Ketone	Carboxylic acid	Ester

62.



The name of the compound represented above is

(A) 2–ethyl–3,4,4–trimethylpentane

(B) 2–ethyl–3,5–dimethylhexane

(C) 2,4,5–trimethylheptane

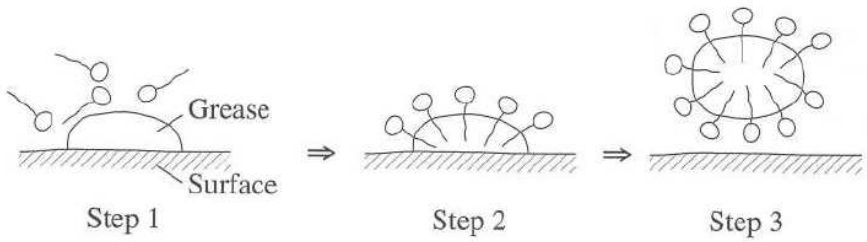
(D) decane.

Short-answer questions

Question 63 (3 marks)

The diagram shows a sequence of steps in the removal of grease from a surface.

Explain the process shown in these steps. **3**



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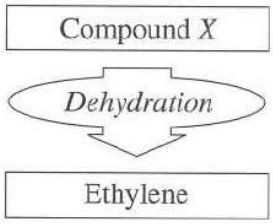
2013 HSC Q32(a)

Question 64 (1 mark)

This diagram shows how ethylene can be formed from compound *X*. **1**



Identify Compound *X*.

..... *2003 HSC Q17(a)*

Question 65 (4 marks)

(a) Write a balanced chemical equation, using structural formulae, for the formation of ethyl butanoate. **2**

(b) Common safety precautions in school laboratories include the use of safety glasses, gloves and lab coats. Justify the use of another safety precaution specifically required to safely make ethyl butanoate. **2**

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2012 HSC Q21

Question 66 (4 marks)

Explain, using a diagram, the cleaning action of a soap in terms of its molecular structure. **4**

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Adapted 2009 HSC Q27(d)(i)

Question 67 (3 marks)

A student created the following models to demonstrate a chemical process.

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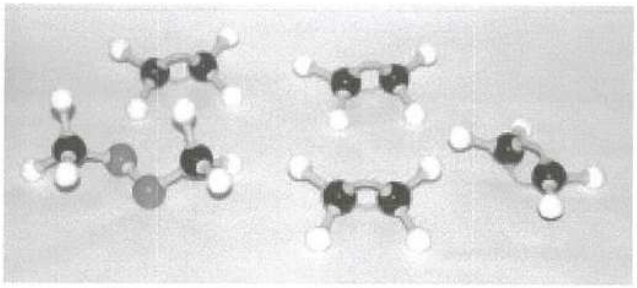
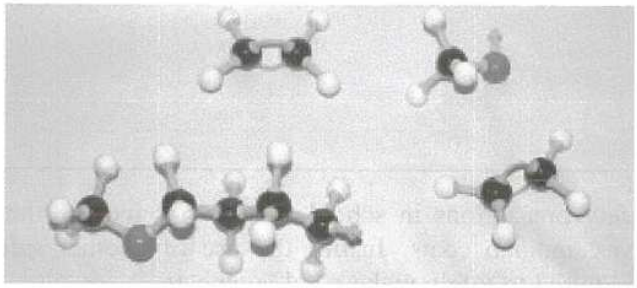
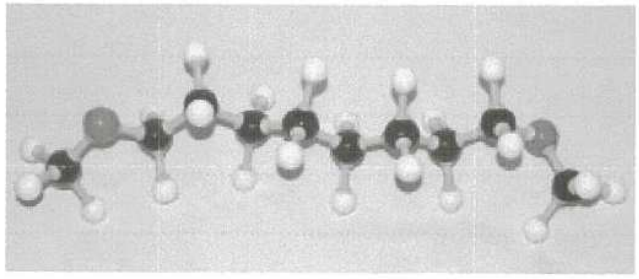


II



III



(a) What is the chemical process being modelled? **1**

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(b) Why are models such as these useful? **2**

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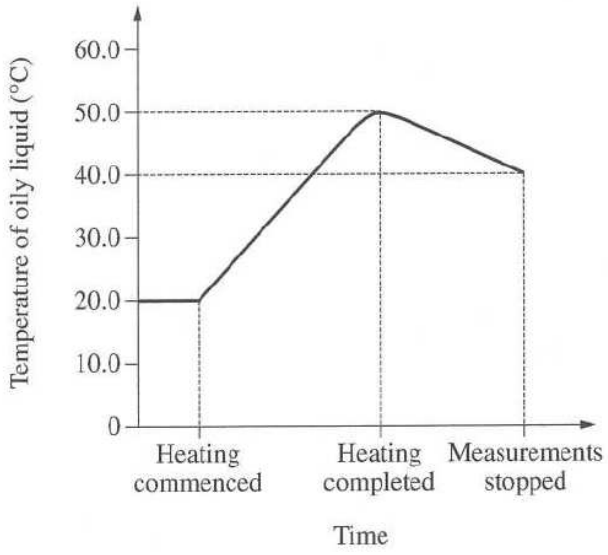
2012 HSC Q22

Question 68 (4 marks)

A 0.259 g sample of ethanol is burnt to raise the temperature of 120 g of an oily liquid, as shown in the graph. There is no loss of heat to the surroundings. **4**



Usin the information shown on the graph, calculate the specific heat capacity of the oily liquid. The enthalpy of combustion of ethanol is 1367 kJ mol^{-1}.

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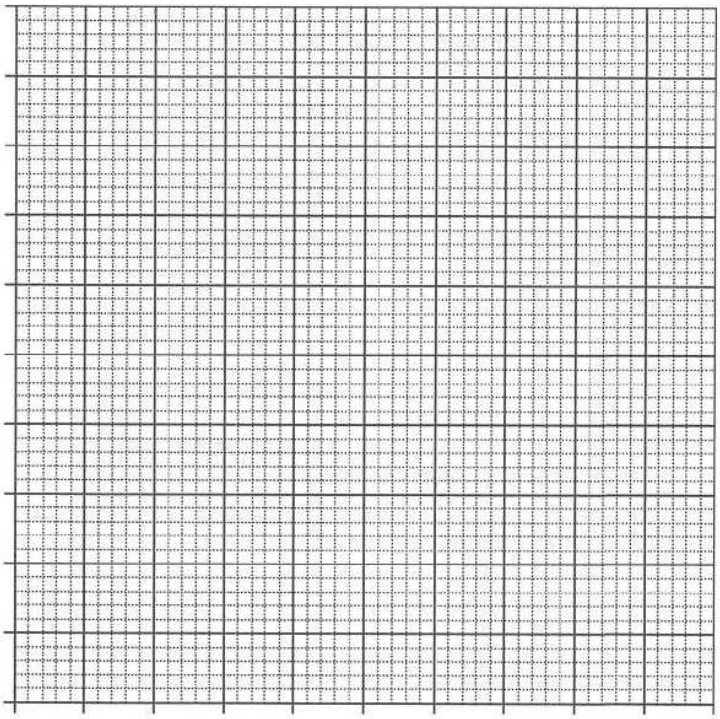
Adapted 2013 HSC Q27

Question 69 (5 marks)

The boiling points of some alcohols are given in the table.

Alkanol	*Boiling point* (°C)
Methanol	65
Ethanol	79
Propan-1-ol	97
Pentan-1-ol	138
Hexan-1-ol	157
Heptan-1-ol	176

(a) Using the data provided, construct a graph that shows the relationship between carbon chain length and boiling point. **3**



(b) Using the graph, predict the boiling point of butan-1-ol. **1**

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(c) What is the intermolecular force responsible for the trend shown in the graph? **1**

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2012 HSC Q31

Question 70 (4 marks)

What features of the molecular structure of ethanol account for its extensive use as a solvent? Include a diagram in your answer. **4**

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2011 HSC Q21

Question 71 (6 marks)

A student prepared the compound methyl propanoate in a school laboratory.

(a) Give a common use for the class of compounds to which methyl propanoate belongs. **1**

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(b) In the preparation of this compound a few drops of concentrated sulfuric acid were added to the starting materials. The mixture was then refluxed for a period of time. **2**

Why was it necessary to reflux the mixture?

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Question 71 continues

Question 71 (continued)

(c) Name the TWO reactants used in preparing the methyl propanoate and draw their structural formulae. **3**

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End of Question 71

2010 HSC Q22

Question 72 (4 marks)

(a) Calculate the mass of ethanol that must be burnt to increase the temperature of 210 g of water by 65°C, if exactly half of the heat released by this combustion is lost to the surroundings. **3**

The enthalpy of combustion of ethanol is 1367 kJ mol L^{-1}.

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(b) What are TWO ways to limit heat loss from the apparatus when performing a first-hand investigation to determine and compare the enthalpy of combustion of different liquid alcohols? **1**

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Adapted 2009 HSC Q20

Question 73 (3 marks)

(a) Write a balanced chemical equation for the complete combustion of 1-butanol. **1**

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(b) A student measured the enthalpy of combustion of three different fuels. The results are shown in the table. **2**

Fuel	*Enthalpy of combustion* ($kJ\ g^{-1}$)
A	–48
B	–38
C	–28

The published value for the enthalpy of combustion of butan-1-ol is 2676 kJ mol L^{-1}.

Which fuel from the table is likely to be 1-butanol? Justify your answer.

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Adapted 2010 HSC Q23

Question 74 (3 marks)

The enthalpy of combustion of ethanol is 1367 kJ mol L^{-1}. In a first-hand investigation to determine the enthalpy of combustion of ethanol, the experimental value determined differed from the theoretical value.

(a) Identify a reason for this difference. **1**

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Question 74 continues

Question 74 (continued)

(b) Calculate the theoretical mass of ethanol required to heat 200 mL of water from 21.0°C to 45.0°C. **2**

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End of Question 74

Adapted 2005 HSC Q17

Question 75 (5 marks)

During your study of hydrocarbons, you conducted an investigation to compare an alkene with its corresponding alkane.

(a) Name the alkene used in your investigation. **1**

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(b) Identify a potential hazard in your investigation, and outline how you addressed this hazard. **2**

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(c) Outline the procedure you used for your investigation. **2**

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Adapted 2005 HSC Q16

Question 76 (5 marks)

The table shows four fuels and their various properties.

Property	*Petrol*	*Kerosene*	*Hydrogen*	*Ethanol*
Heat of combustion (kJ mol^{-1})	5460	10 000	285	1370
Boiling point (°C)	126	300	–253	78
Density (g mL^{-1})	0.69	0.78	n/a	0.78
Average molar mass (g mol^{-1})	114	210	2	46

(a) Which fuel provides the greatest amount of energy per gram? **1**

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(b) A car has an 80 L petrol tank. Calculate the energy released by the complete combustion of one full tank of petrol. **2**

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(c) How many litres of hydrogen gas at 25°C and 100 kPa would be needed to supply the same amount of energy as 80 L of petrol? **2**

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2008 HSC Q24

Question 77 (3 marks)

When hexanoic acid and ethanol are mixed together under certain conditions, esterification occurs. **3**

Describe the conditions necessary for this reaction and give the structural formulae and names of the products.

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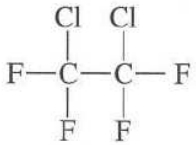
2007 HSC Q23

Question 78 (1 mark)

What is the systematic name of the CFC in the diagram? **1**



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2002 HSC Q25(a)

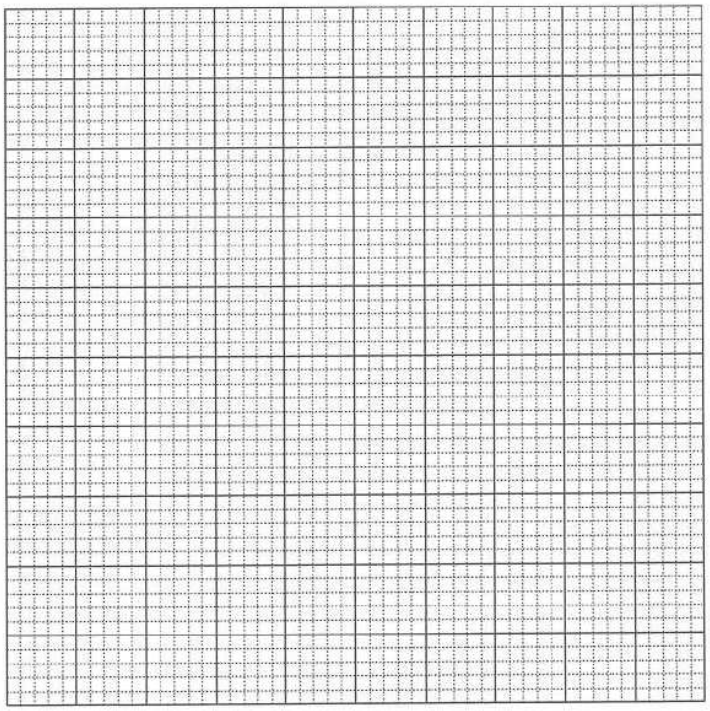
Question 79 (5 marks)

The enthalpy of combustion ($-\Delta H_c$) of three alcohols were determined.

The results are shown in the table.

Alcohol	*Enthalpy of combustion ($kJ\ g^{-1}$)*
Methanol	480
Ethanol	920
Butan-1-ol	1800

(a) Plot a graph of the enthalpy of combustion versus the molar mass for the three alcohols. **3**



Molar mass

Question 79 continues

Question 79 (continued)

(b) (i) Use the graph to estimate the enthalpy of combustion of propan-1-ol. 1

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(ii) The theoretical value for the heat of combustion of propan-1-ol is more than 2000 kJ mol^{-1}. 1

Suggest a chemical reason, other than heat loss, for the difference between this value and the estimated value from part (b) (i).

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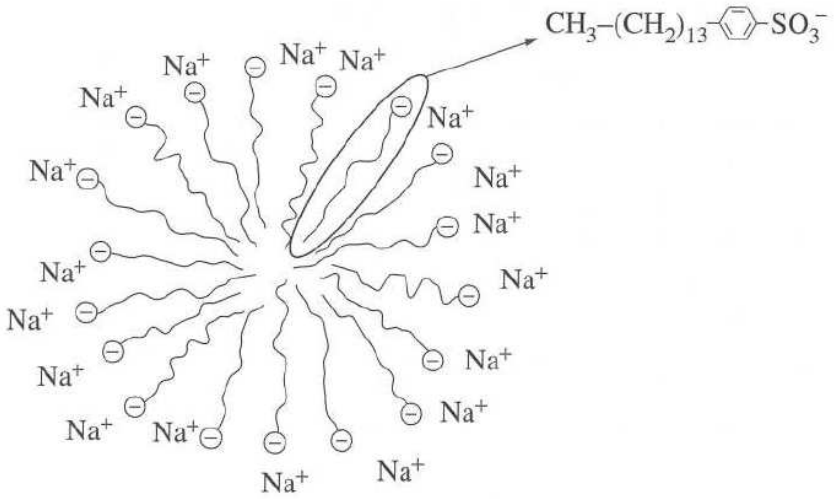
End of Question 79 *Adapted 2007 HSC Q24*

Question 80 (6 marks)

The diagram represents how one class of molecules assembles in water to form a structure called a *micelle*.



(a) Identify the class of molecules shown. 1

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Question 80 continues

Question 80 (continued)

(b) Account for the formation of a micelle. **2**

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(c) Explain what happens when oil is added to water containing these molecules. **3**

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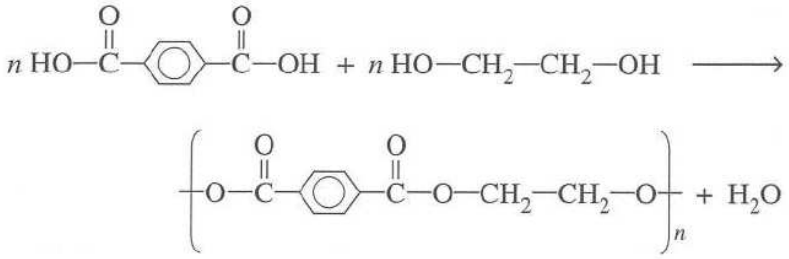
End of Question 80 *2006 HSC Q29(b)(i)-(iii)*

Question 81 (1 mark)

Name the type of polymerisation shown in the following reaction: **1**



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2002 HSC Q18(a)

Question 82 (5 marks)

You performed a first-hand investigation to prepare an ester by reflux.

(a) Identify the products formed when propanoic acid and butanol are refluxed with acid catalyst. **1**

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(b) Draw a fully labelled diagram of the equipment assembled for use. **2**

(c) Outline the advantages of using reflux to prepare the ester. **2**

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2003 HSC Q21

Question 83 (3 marks)

(a) Write a balanced chemical equation for the complete combustion of ethanol. **1**

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(b) A mass of 72.5 g of ethanol was burnt completely in air. Calculate the volume of carbon dioxide that was produced at 25°C and 100 kPa. **2**

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2003 HSC Q22

Question 84 (5 marks)

Discuss some environmental, social and economic issues as a result of obtaining hydrocarbons from the Earth to use in the synthesis of chemicals. **5**

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Question 85 (4 marks)

Proteins are a condensation polymer that occurs in nature. These natural polymers are essential for the survival of organisms. The monomer building blocks in a protein are amino acids that undergo condensation polymerisation to form an amide. The bond that forms between two amino acids is called a peptide link and two amino acids joined together are called a dipeptide.

(a) What structure is formed when a long chain of amino acids are joined together by condensation polymerisation? **1**

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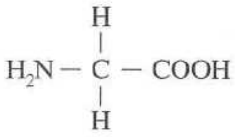
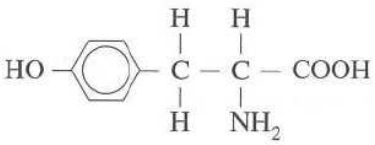
(b) The structure of two amino acids is shown. Write an equation in the space below using correct structural formulae to show how glycine reacts with alanine to form a dipeptide and releases a molecule of water in doing so. **2**

Glycine



Tyrosine



(c) Polymers that are formed by addition polymerisation do not require the removal of a molecule of water. Identify the structure that is necessary in monomers for addition polymerisation to occur to form a polymer? **1**

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Question 86 (4 marks)

A student studying the mass change that occurs during fermentation added glucose, water and yeast to a flask and stoppered the flask with some cotton wool.

The student measured the mass of the flask daily for seven days. The table shows the data collected.

Day	*Mass* (g)
1	381.05
2	376.96
3	373.42
4	370.44
5	370.42
6	370.40
7	370.39

(a) Calculate the moles of CO_2 released between days 1 and 7. **1**

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(b) Calculate the mass of glucose that underwent fermentation between days 1 and 7. Include a balanced chemical equation in your answer. **3**

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2006 HSC Q18

Question 87 (4 marks)

Ethanol produced by the fermentation of carbohydrates, such as sugars and starches, is a biofuel. 4

Outline the need for sustainable biofuels and how they differ from fossil fuels in terms of renewability.

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Question 88 (4 marks)

Water and ethanol are both used as solvents. 4

Explain the differences and similarities in their solvent behaviour in terms of their molecular structures. Include a diagram in your answer.

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2009 HSC Q17

Question 89 (9 marks)

Polymers can be made synthetically by polymerisation reactions.

(a) Draw three repeat segments for the structure of the polymer formed from this monomer: $CH_2=CH$ (Cl) **1**

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(b) Give both the common name and the IUPAC name of the monomer above and the name of the polymer it forms. **2**

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(c) Indicate the type of polymerisation that is involved in (a) and identify the structure that allows this type of polymerisation to occur. **2**

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(d) Explain the relationship between the structures and properties of TWO different polymers from ethylene, and their uses. **4**

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Question 90 (3 marks)

Explain why alkanes and their corresponding alkenes have similar physical properties, but very different chemical properties. **3**

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2002 HSC Q17

Answers

Module 7: Organic Chemistry

Multiple choice

1. C	**2.** B	**3.** A	**4.** D	**5.** A	**6.** C	**7.** D	**8.** A
9. A	**10.** C	**11.** B	**12.** D	**13.** C	**14.** D	**15.** C	**16.** B
17. D	**18.** C	**19.** D	**20.** D	**21.** D	**22.** B	**23.** D	**24.** B
25. B	**26.** D	**27.** C	**28.** C	**29.** A	**30.** C	**31.** D	**32.** B
33. B	**34.** B	**35.** A	**36.** C	**37.** B	**38.** C	**39.** B	**40.** C
41. D	**42.** C	**43.** A	**44.** C	**45.** A	**46.** B	**47.** C	**48.** A
49. C	**50.** D	**51.** D	**52.** A	**53.** D	**54.** D	**55.** B	**56.** B
57. B	**58.** A	**59.** D	**60.** B	**61.** C	**62.** D		

Explanations

1. C The equation shows that one mole of butan–1–ol produces 4 moles of $CO_2(g)$ when burnt in excess $O_2(g)$. So 2 moles of butan–1–ol will produce 8 moles of $CO_2(g)$. So (C) is the answer.

2. B Enthalpy of combustion (heat of combustion, ΔH) in the table is in kJ mol^{-1}, so ΔH needs to be divided by the molar mass to determine the energy (ΔH) in kJ per 1.00 g for each one.

- CO, $\Delta H = -\frac{233}{28.01} = -8.32$ kJ g^{-1}
- CH_4, $\Delta H = -\frac{890}{16.042} = -55.48$ kJ g^{-1}
- C_2H_2, $\Delta H = -\frac{1300}{26.036} = -49.93$ kJ g^{-1}
- C_2H_6, $\Delta H = -\frac{1560}{30.068} = -51.88$ kJ g^{-1}

CH_4 produces the greatest amount of energy per 1.00 g, so (B) is the answer.

3. A The equation for this reaction is: $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(l)$. The addition of a water molecule across the double bond of the ethylene molecule is hydration as in (A), and not the reverse as in (B). This reaction has nothing to do with polymerisation, so (C) and (D) are irrelevant.

4. **D** The equation for this reaction is: $C_6H_{12}O_6(aq) \xrightarrow{yeast} 2C_2H_5OH(aq) + 2CO_2(g)$
So the products are ethanol and carbon dioxide, as in (D).

5. **A** Butan-1-ol has one more carbon in its chain than propan-1-ol and so a greater molar mass. So butan-1-ol has a greater boiling point. So (A) is the answer. Both compounds are colourless, non-electrolytes and have similar densities, so these properties cannot be used to distinguish them. So (B), (C) and (D) are incorrect.

6. **C** The acid group on the left has three carbon atoms, so this ester is derived from propanoic acid. The alcohol group on the right has four carbon atoms, so this ester is derived from butanol. Hence its name is butyl propanoate, as in (C).

7. **D** Ethene (ethylene, C_2H_4) reacts with benzene to form styrene, which polymerises to form polystyrene (a polymer). So (D) is the answer. Ethene can also polymerise directly to form polyethylene, but this is not the reaction shown. Cellulose is a polymer of glucose, so (A) is incorrect. Ethanol can be made by hydrating ethene, not by polymerisation, so (B) is incorrect. Glucose is not formed from ethene, so (C) is incorrect.

8. **A** The correct 'preferred IUPAC name' is 2-chloro-3-fluorobutane. Remember, to determine the correct IUPAC name: (1) if there is more than one type of halogen, you name them alphabetically, then (2) number the chain (left to right or right to left), so that the numbers for the halogen groups give the lowest sum, and (3) if this sum is the same, choose the combination that gives the smallest number to the first named halogen. Hence the compound is 2-chloro-3-fluorobutane, as in (A).

[Note: In a much earlier, superseded version of IUPAC nomenclature, the most electronegative halogen was given the lowest number, if the sum was the same. According to this superseded method, the name of the compound would be 3-chloro-2-fluorobutane as in (D), as fluorine is more electronegative than chlorine. However, this system is no longer used – so (D) is incorrect.]

9. **A** In forming the polymer, the double bond of the monomer needs to become a single bond to form the polymer. The branch carboxylic group (–COOH) remains unchanged. This is done in an addition reaction. So (A) is the answer. (B), (C) and (D) are all incorrect as all three processes would involve the loss of atoms from the monomer in forming the polymer.

10. **C** The isomers of a compound must have the same molecular formula. They will not contain any different or extra functional groups, e.g. C=O, –OH. Only (C) has the same molecular formula as 1–butanol, i.e. $C_4H_{10}O$. So (C) is the answer.

11. B Fermentation is an anaerobic (no oxygen) process that converts glucose into ethanol and carbon dioxide, as shown in (B). (A) is incorrect as the product is not ethanol. (C) is incorrect as it is showing respiration, not fermentation. (D) is incorrect as it is an aerobic process.

12. D The polymers shown are polyethylene, polystyrene, polyvinyl chloride and a carbohydrate polymer. Since the container is labelled 'made from plants', only the carbohydrate polymer in (D) would be from a plant and is therefore the answer. Since the monomers ethylene, styrene and vinyl chloride are derived from fossil fuels, (A), (B) and (C) are incorrect.

13. C $\Delta H = -2021$ kJ mol^{-1}, so $n_{\text{propan-1-ol}} = \frac{1530}{2021}$

From the given equation, 1 mol propan-1-ol produces 4 mol H_2O

Molar mass of $H_2O = (2 \times 1.008) + (1 \times 16.00) = 18.016$ g mol^{-1}

Mass $H_2O = \frac{1530}{2021} \times 4 \times 18.016 = 54.56$ g ≈ 55 g ... as in (C)

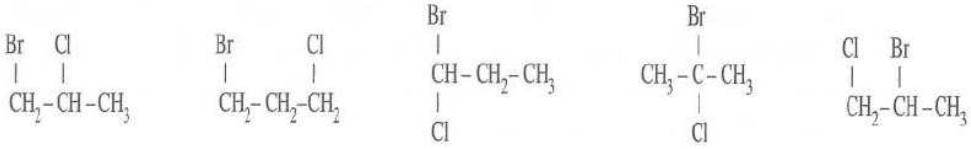
14. D 2-propanol is a secondary alcohol – and if oxidised, it will form propanone (a ketone). Propanone cannot undergo further oxidation. So both (A) and (B) are incorrect. 1-butanol can initially oxidise to form butanal and then further oxidise to butanoic acid, but not to propanoic acid. So (C) is incorrect. 1-butene (an alkene) has a double bond between the first two carbon atoms. Oxidation can occur across this double bond which may, depending on the reaction conditions, split the molecule into two smaller carbonyl molecules, both of which can be further oxidised to acids – in this case methanoic (which could undergo further oxidation) and propanoic acid. So (D) is the answer.

15. C 2-butanol is a secondary alcohol since the –OH group is connected to the second carbon. Oxidation of a secondary alcohol produces a ketone, so butanone would be formed, as in (C). The primary alcohol, 1-butanol, would be oxidised to butanal (an aldehyde) under mild conditions and further oxidised to butanoic acid (a carboxylic acid), so (A) and (D) are not the products. Oxidation will not produce an ester, so (B) is incorrect.

16. B The melting and boiling points decrease as the molecule size decreases due to decreased dispersion forces between the molecules. So the molecules, in decreasing molecule size and therefore decreasing MP and BP are: ethanoic acid, ethanol, fluoroethane, ethane ... as in (B).

17. D When bromine reacts with propene, it adds across the double bond to form 1,2-dibromopropane: $CH_3–CH = CH_2(g) + Br_2(aq) \rightarrow CH_3–CHBr–CH_2Br(l)$

18. C Isomers have the same molecular formula. By drawing all the possible isomers (making sure to eliminate any that are duplicates drawn from the opposite perspective), it is found that there are 5 isomers, as in (C):



19. D Pentan-1-ol is $C_5H_{11}OH$

$M(C_5H_{11}OH) = (5 \times 12.01) + (12 \times 1.008) + (1 \times 16.00) = 88.146 \text{ g mol}^{-1}$

No. moles $= \frac{108}{2800}$

Mass of alcohol $= \frac{108}{2800} \times 88.146 = 3.399$ g

$\therefore$ mass of alcohol ≈ 3.40 g ... as in (D).

20. D Specific heat of a substance is a measure of its ability to store heat energy. It is the amount of heat energy required to raise the temperature of 1 g of the substance by 1°C, as in (D). It does not refer to boiling or melting the substance, so (A) and (B) are incorrect. (C) is incorrect as it does not specify the amount of the substance.

21. D The double bond in the ethene molecules (C_2H_4) is broken as the molecules add together by polymerisation, to form the addition polymer, poly(ethene), i.e. polythene, as in (D): $n(C_2H_4) \rightarrow (–CH_2–CH_2–)_n(s)$

There is no reaction between the molecules to eliminate a by-product, so it is not condensation, as in (A). Water is not involved, so it is not hydrolysis, as in (B). There is no electron transfer, so it is not oxidation/reduction, as in (C).

22. B Isomers have the same molecular formula. There are two isomers with the molecular formula $C_2H_3F_3$ – the compound shown, which is 1,1,1–trifluoroethane, and the compound 1,1,2–trifluoroethane. So (B) is the answer.

23. D The polymer shown is polystyrene. The monomer ($C_6H_5.CH=CH_2$) from which it is formed is commonly known as styrene (= its preferred IUPAC name). The systematic IUPAC name for styrene is ethenylbenzene. So (D) is the answer.

24. B Formula of ethanol: C_2H_5OH

Molar mass (ethanol) = $(12.01 \times 2) + (1.008 \times 6) + (16.00 \times 6) = 46.068$ g mol^{-1}

$q = m\,c\,\Delta T = 1$ kg $\times$ 4.18×10^3 J kg^{-1} K^{-1} $\times$ (100–50)°C = 209,000 J = 209 kJ

Ethanol required = $\dfrac{209 \text{ kJ}}{1367 \text{ kJ mol}^{-1}} = 0.1529$ mol = 0.1529×46.068 g mol^{-1} = 7.04 g

So (B) is the answer.

25. B Water is released in a condensation polymerisation reaction if an –OH group in the monomer is eliminated along with a hydrogen atom. The polymerisation of glucose to cellulose is a condensation reaction as water molecules are released as the monomers join up. So (B) is the answer. The other monomers, ethene (ethylene), styrene and vinyl chloride, each contain a double bond and so undergo addition polymerisation reactions, which do not involve the release of water. So (A), (C) and (D) are incorrect.

26. D The longest carbon chain contains 5 carbon atoms, so the name is derived from pentane and not butane. So (A) and (B) are incorrect. The second carbon atom has a methyl group attached, not an ethyl group. So (C) is incorrect. Only (D) correctly names this compound as 1-chloro-2,3-dimethylpentane.

27. C $\Delta H = m\,c\,\Delta T$

21.2×10^3 J = $(336.1 - 215.6) \times 10^{-3}$ kg $\times$ $(4.18 \times 10^3$ J kg^{-1} K$^{-1})$ $\times$ $(71.0 - T_0)$

$21.2 \times 10^3 = 120.5 \times 4.18 \times (71.0 - T_0)$

$71.0 - T_0 = \dfrac{-21.2 \times 10^3}{-120.5 \times 4.18} = 42.08938$

$\therefore T_0 = 71.0 - 42.08938 = 28.9$°C ... so (C) is the answer.

28. C Sulfuric acid is a dehydrating agent. It reacts with alcohols to remove an –H and an –OH from adjacent carbon atoms to form a double bond, which will decolourise bromine water. The only alcohol is given in (C), so this the answer. Concentrated sulfuric acid will react with C_6H_{12} ... if it is hexene, it will produce hexanol that will not decolourise bromine water, but if C_6H_{12} is cyclohexane, there will be no reaction. In either case, (A) is incorrect. Hexane (C_6H_{14}) will not react with concentrated sulfuric acid, so (B) is incorrect. $C_6H_{11}COOH$ is a fatty acid and does not react with sulfuric acid, so (D) is incorrect.

[Note: The compound $C_6H_{11}OH$ is cyclohexanol. Even though you may not be familiar with this compound, you should have been able to deduce that it was the only alcohol in the list because it has an –OH group.]

29. A The type of alcohol used is the independent variable since the type of alcohol used is determined by the investigator. So (A) is the answer. The amount of water used and the amount of each alcohol used should be identical. These would be controlled variables. So (B) and (C) are incorrect. The temperature change is what is being measured and so is the dependent variable. So (D) is incorrect.

30. C The active ingredients in perfumes are usually a mixture of esters. Esters are usually oily liquids, so they are largely insoluble in water, but soluble in ethanol. So (C) is the answer. Since ethanol has to be manufactured and water is readily available, ethanol is not cheaper to produce, so (A) is incorrect. Ethanol does have a definite characteristic odour, although not unpleasant, so (B) is incorrect. Ethanol is slightly less dense than water, not significantly less, so (D) is incorrect.

31. D Bromine (Br_2) reacts with alkenes by adding bromine atoms across the double bond, as in (D). Bromine reacts with alkanes (saturated hydrocarbons) by substitution. So (C) is incorrect. Bromine is a diatomic molecule containing two identical bromine atoms, so it is non-polar. So (A) and (B) are incorrect.

32. B Each formula shows an ester formula with the acid group on the left and the alcohol group on the right. Butanoic acid is a four carbon acid and pentanol is a five carbon alcohol. Only (B) shows four carbon atoms in the acid group on the left and five carbon atoms in the alcohol group on the right.

33. B Fermentation: $C_6H_{12}O_6(aq) \xrightarrow{zymase} 2C_2H_5OH(aq) + 2CO_2(g)$

Molar mass $CO_2 = 12.01 + (2 \times 16.00) = 44.01$ g mol^{-1}

$\therefore$ mol $CO_2 = \frac{5.68}{44.01} = 0.1291$

Molar mass (ethanol) $= (12.01 \times 2) + (1.008 \times 6) + (16.00 \times 6) = 46.068$ g mol^{-1}

From the equation: moles CO_2 produced = moles C_2H_5OH produced

So $0.1291 = \frac{\text{mass of } C_2H_2OH}{46.068}$

$\therefore$ mass C_2H_5OH produced $= 0.1291 \times 46.068 = 5.95$ g ... so (B) is the answer.

34. B $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2(g)$

From equation, one mole $C_6H_{12}O_6$ produces two moles CO_2.

Molar mass $C_6H_{12}O_6 = (12.01 \times 6) + (1.008 \times 12) + (16.00 \times 6) = 180.156$ g mol^{-1}

Molar mass $CO_2 = 12.01 + (16.00 \times 2) = 44.01$ g mol^{-1}

$\therefore$ 180.156 g $C_6H_{12}O_6 \rightarrow 2 \times 44.01 = 88.02$ g CO_2

Mass of CO_2 produced $= 6.50 \times \frac{88.02}{180.156} = 3.176$ g ≈ 3.18 g ... as in (B).

35. A Molar mass: • pentane: $C_5H_{12} \approx 72$ g mol^{-1} • butan-1-ol: $C_4H_9OH \approx 74$ g mol^{-1}
• propanoic acid: $C_2H_5COOH \approx 74$ g mol^{-1}

The molecular weights are approximately the same, so intermolecular forces need to be considered. There are more intermolecular forces in the acid compared to the alcohol, and in the alcohol compared to pentane. So pentane will have the lowest boiling point and propanoic acid will have the highest boiling point, as in (A).

36. C While there is a chain of six C atoms across the page, the methyl group attached to the left end extends the chain to seven C atoms – so the IUPAC name is derived from heptane and not hexane. So (A) and (B) are incorrect. The functional –OH group is joined to the fifth C atom from the left and the third from the right. IUPAC names use the lower number, so this compound is heptan-3-ol … as in (C), and so (D) is incorrect.

37. B An isomer has the same number of each atom in its compounds, but a different structure. This compound is dichloro-propane. The two chlorine atoms can be in any one of the following positions: 1,1–, 1,2–, 1,3– or 2,2. So there are 4 isomers, as in (B).

[Note: Any other apparent isomers are equivalent to one of these four.]

38. C Mass, m (ethanol) = 133.20 – 132.05 = 1.15 g

Molar mass, M (ethanol) = (12.01 × 2) + (1.008 × 6) +(16.00 × 6) = 46.068 g mol^{-1}

Moles, n (ethanol) $= \frac{m}{M} = \frac{1.15}{46.068} = 0.02496$ mol

$q = m\,c\,\Delta T = 0.300 \times (4.18 \times 10^3) \times (45.5 - 25.0) = 25{,}707$ J = 25.707 kJ

Molar enthalpy of combustion, $\Delta H = -\frac{25.707}{0.02496} = -1029.9$ kJ mol^{-1} … as in (C).

39. B Butan-1-ol has the formula: C_4H_9OH, so its molar mass = 74.12 g mol^{-1}

ΔH(butan-1-ol) = –2676 kJ mol^{-1}
= –2676 kJ per 74.12 g
= –36.10 kJ g^{-1} … as in (B)

40. C The boiling points increase as the molecule size increases due to increased dispersion forces between the molecules. So the molecules, in increasing molecule size and therefore increasing BP are: ethane, butane, ethanol, butanol ... as in (C).

41. D A condensation polymer is formed by the elimination of a water molecule when the pairs of monomer molecules are joined together. It can be reversed by hydrolysis (the addition of a water molecule) to form its monomers. The correct monomers are those which result in the given polymer, after an –OH has been removed from one end of one monomer and an –H from one end of the other monomer. Only (D) is possible.

42. C When naming an alkane that has more than one substituent present, either on the same carbon atom or on different carbon atoms, list them alphabetically. So chlorine is named before fluorine. So (A) and (B) are incorrect. Numbering from the right gives a lower set of numbers. Cl is attached to the first C atom, not the second. So (C) is the answer, and (D) is incorrect.

43. A This is the reaction between ethanol, an alcohol and ethanoic acid, a carboxylic acid. The reaction between an alcohol and a carboxylic acid is esterification, as in (A). It does not involve addition of water, which is hydration, nor does it form a long chain macromolecule as in polymerisation, and it does not involve changing an oxidation state as in reduction, so (B), (C), (D) are incorrect.

44. C

Methanol:	molar mass 32 g mol^{-1},	so $\Delta H = 22.7 \times 32 = -726$ kJ mol^{-1}
Ethanol:	molar mass 46 g mol^{-1},	so $\Delta H = 29.6 \times 46 = -1362$ kJ mol^{-1}
Propanol:	molar mass 60 g mol^{-1},	so $\Delta H = 33.6 \times 60 = -2016$ kJ mol^{-1}
Octane:	molar mass 114 g mol^{-1},	so $\Delta H = 47.8 \times 114 = -5449$ kJ mol^{-1}

$\therefore$ propanol is the fuel. So (C) is the answer.

[Note: 1. Propanol exists as either propan-1-ol or propan-2-ol and each has a specific heat of combustion, so it is incorrect to refer to it as just 'propanol'. 2. Octane is NOT petrol – the major hydrocarbon in petrol is 2,2,4–trimethylpentane, just one isomer of octane.]

45. A This compound has three C atoms. Hence it is propane, not pentane. The longest C chain needs to be numbered so that the halogen groups have the lowest numbers. So the Cl atom is referred to as 1-chloro, and the two F atoms (hence difluoro) as 1,2-difluoro. The halogen atoms must be named in alphabetical order. Hence the name is 1-chloro-1,2-difluoropropane … as in (A).

46. B In addition polymerisation, the two C atoms on either side of a double bond join up to form a long carbon chain, which is the backbone of the polymer. In this case the backbone will consist of $–CH_2–C–CH_2–C–CH_2–C–$ etc. The side groups (CH_3 and $COOCH_3$) will remain joined to the C atom they were originally joined to in the monomer. So (B) is the only possible answer.

47. C The longest carbon chain has six carbon atoms, so the name is derived from hexane. The functional group –CHO makes it an hexanal. The carbon atoms are numbered from the functional group, so numbering is from right to left. The attached groups are then listed alphabetically with halogen atoms shown before alkyl side chains and each is listed with the number of the carbon to which it is attached. Hence the name is 5-bromo-4-chloro-4-methylhexanal … as in (C).

48. A *P* = condenser … this is water cooled so that volatile flammable vapours re-condense and do not escape and so are returned to the reaction flask.

Q = boiling chips … these promote even boiling without 'bumping' and so help to prevent hot mixture being expelled explosively up through the condenser.

R = electric heating jacket … this is used to safely provide heat as the reactants and ester are flammable.

Only (A) has the correct combination for *P*, *Q* and *T* and so is the answer.

49. C The longest chain of C atoms including the double bond contains 6 C atoms, hence the compound is a hexene. The chain is numbered to give C atoms containing the double bond the lowest number, so it is a 1-hexene compound, and answers (A) and (B) are incorrect. Each functional group should be in the correct order from lowest to highest C atom, and the number of the C atom for every group should be specified, e.g. both dimethyl groups are on C4). Hence the compound is 3-iodo-4,4-dimethyl-1-hexene … as in (C), and not (D).

50. D The reactants, ethanol and ethanoic acid, would be added first in either order (Steps 5, 3 or 3, 5). So (B) and (C) are incorrect. Concentrated sulfuric acid is then added as a catalyst and 'water absorber' (step 2), and the mixture is then refluxed (step 1). Hence (D) is the answer and (A) is incorrect.

[Note: This is not a neutralisation reaction, so an indicator as in Step 7 is unnecessary. Ethene is not a chemical used in esterification, so Step 4 is not required. Distillation of the mixture would be used to isolate the ester from the reaction mixture in the flask, so Step 6 is not needed.]

51. D Esterification involves an acid and an alcohol reacting to form an ester. Only (C) and (D) show the correct reactants, e.g. methanol + ethanoic acid. So (A) and (B) are incorrect. Both (C) and (D) show H^+ acting as a catalyst. Methanol + ethanoic acid react to form the ester, methyl ethanoate … as correctly shown in (D). They do not form the ester, ethyl methanoate. So (C) is incorrect.

52. A The boiling points of each group increase with increasing molecular mass due to increasing carbon chain length. So (A) is the answer and (D) is incorrect. The longer the carbon chain length, the greater the dispersion forces between molecules and so more energy is required to separate them. So (C) is incorrect. Dispersion forces increase with increasing molecular mass. So (B) is incorrect.

53. B Carboxylic acids have both hydrogen bonding and double-bonded oxygen to overcome and so have higher boiling points than alcohols and alkanes. Alcohols have higher boiling points than alkanes as they also have hydrogen bonding between alcohol molecules to overcome when boiling them. Alkanes have only dispersion forces to overcome to boil them. So (B) is the only correct answer.

54. D (B) and (D) are both strong acids and fully ionised. However, 0.2 M nitric acid has double the $[H^+]$ compared 0.1 M hydrochloric acid and so will a higher $[H^+]$. Hence the correct answer is (D), and not (B). Ethanoic acid is a weak acid, with $pK_a << 5$. So it will have a much lower $[H^+)$, i.e. a higher pH, than the other acids. So (A) is incorrect. NaOH is basic and so has a pH > 7, so (B) is incorrect.

55. B The product and reactants would differ in boiling point and so could be separated by *distillation* – hence the apparatus shown in (B) would be used. (A), (B) and (D) would not be used, as the apparatus is (A) would be used for titration, (C) for refluxing (as when preparing the ester), and (D) would be used for filtration

56. B NaOH, HNO_3 and Pt are not used as catalysts for this reaction, so (A), (C) and (D) are incorrect, whereas H_2SO_4 is. So (B) is the answer.

57. B The compound is named to give the lowest number for the carbon atom at the start of the double bond, so the chain must be counted from the right to give 2-hexene. So (A) and (C) are incorrect. If the double bond starts at carbon 2, the iodine is on carbon 3. Hence the compound is 2-iodo-2-hexene. So (D) is the answer and (B) is incorrect.

58. A Butene has a double bond. A double bond is very reactive, so chlorine reacts by adding across the double bond. Such a reaction is called an 'addition' reaction. So (A) is the answer.

59. **D** Isomers have the same molecular formula. Compounds (II) and (IV) both have the same formula, C_4H_5Cl. So (D) is the correct answer. (A) is incorrect as (I) and (II) contain 7 H and 5 H atoms respectively. (B) is incorrect as (I) and (III) contain 4 C and 5 C atoms respectively. (C) is incorrect as (I) and (IV) contain 7 H and 5 H atoms respectively.

60. **B** The carbon chain with the –C=O functional group comes from the carboxylic acid. This is a four carbon chain so the acid was butanoic acid. The other chain has two carbons so the alcohol was ethanol. So (B) is the answer.

61. **C** A primary alcohol oxidises to form an aldehyde and if it is a strong oxidising agent as in this question, it will then go on to be further oxidised to a carboxylic acid. A secondary alcohol oxidises to form a ketone (which cannot be further oxidised). A tertiary alcohol does not usually oxidise (and if oxidised, it requires a lot of energy). So (C) is the answer.

62. **D** The longest carbon chain contains 7 carbon atoms, so the name is derived from heptane and not pentane (5 C atoms) or hexane (6 C atoms) or decane (10 C atoms). So (A), (B) and (D) are incorrect. Along the 7C backbone, there are 3 methyl groups (at C2, C4 and C5). Hence the correct name for this compound is 2,3,5-trimethylheptane. Hence (D) is the answer.

Short-answer questions

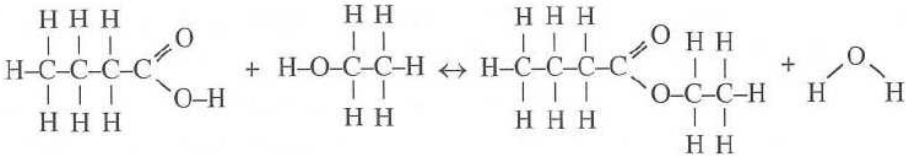
63. *Step 1* shows an organic, non-polar, grease sample adhering to a surface and surfactant molecules, e.g. soap molecules, approaching the grease. The surfactant molecules have a hydrophilic head, as well as a hydrophobic tail that is a non-polar hydrocarbon chain.

Step 2 shows the non-polar tails of the surfactant molecules dissolving in the non-polar grease. Being hydrophilic, the heads of the surfactant remain at the surface of the grease where the water molecules and charged heads of the surfactant molecules form polar hydrogen bonding.

Step 3 shows the grease being removed from the surface. This indicates that the grease sample has been emulsified.

65. Ethanol

65. (a)

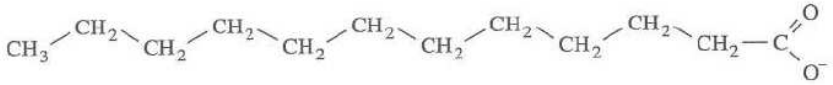


(b) *Any ONE of the following:*

- Heat mixture using an electric heating jacket, to prevent a fire as both reactants and ester products are flammable.
- Add porous pot (boiling chips) to promote even boiling without 'bumping' and to prevent any hot mixture being expelled explosively through the condenser.
- Use a water-cooled condenser to prevent the escape of vapours of volatile, flammable, and sometimes unpleasant-smelling reactants.
- Use a round-bottomed flask to heat more evenly and avoid cracking the glass.
- Add only a small amount of concentrated sulfuric acid catalyst, using a dropper bottle because sulfuric acid is highly corrosive and so is dangerous to use.

[Note: Porous pot should be used and NOT marble chips, as marble chips would react with the sulfuric acid catalyst.]

66. When soap dissolves in water, the anion is freed from the cation. A soap anion consists of a long non-polar hydrocarbon chain and a polar COO^- group:



The non-polar end is grease-soluble and so attaches to the non-polar dirt, fats or oils. The polar end sticks out and forms hydrogen bonds with water and repels grease molecules. The soap anion therefore helps to emulsify the grease by keeping the grease molecules suspended (dispersed) throughout the water, enabling them to be washed away.

67. (a) Polymerisation OR Addition polymerisation

(b) Such models allow us to visualise the shapes and structures of the molecules in 3D. They also simplify the process and so make it easier to understand how the molecules behave in polymerisation.

68. Mass ethanol, $m = 0.259$ g Mass oil = 120 g = 120×10^{-3} kg

Molar mass (ethanol), $M = (2 \times 12.01) + (6 \times 1.008) + (1 \times 16.00) = 46.068$ g mol^{-1}

Moles ethanol burnt ($n_{ethanol}$) $= \frac{m}{M} = \frac{0.259}{46.068} = 5.62 \times 10^{-3}$ moles

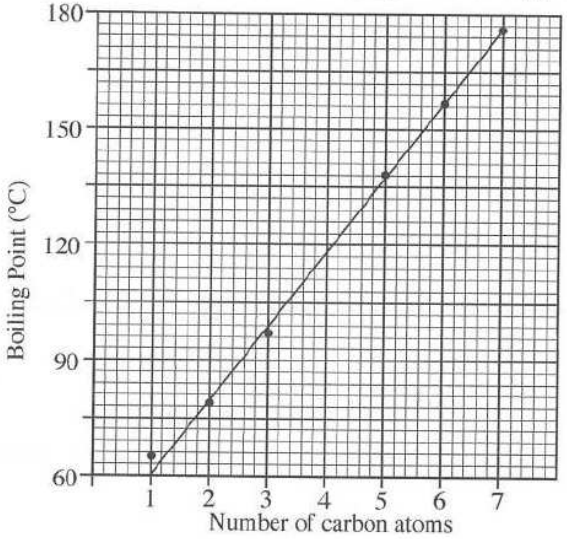
Heat produced, $\Delta H = \Delta_c H \times n_{ethanol} = 1367 \times 5.62 \times 10^{-3}$ kJ

But $\Delta H = q = m \times C \times \Delta T = 120 \times 10^{-3} \times C \times (50.0 - 20.0)$

$\therefore$ Specific heat capacity, $C = \frac{1367 \times 5.62 \times 10^{-3}}{120 \times 10^{-3} \times 30.0} = 2134.84$ J kg^{-1} K^{-1}

$= 2.13$ kJ kg^{-1} K^{-1}

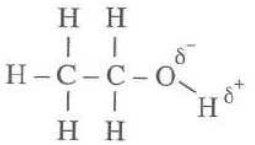
69. (a) *Relationship between carbon chain length and boiling point*



(b) 118°C

(c) Dispersion forces
OR Van der Waals dispersion forces

70. Ethanol has a non-polar hydrocarbon chain (CH_3–CH_2–) end that is hydrophobic. This creates dispersion forces with non-polar molecules, e.g. low molecular weight hydrocarbons, natural oils and iodine, so they are attracted to that end. Hence ethanol can be used as a solvent in medicines and used in fuels. The polar –OH end of ethanol is hydrophilic. It is also capable of hydrogen bonding. This allows ethanol to attract other ethanol molecules, as well as water and other polar molecules (dipole-dipole attraction). Hence ethanol is a solvent for such compounds.

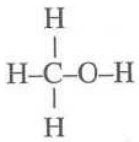


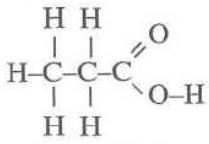
ethanol

71. (a) *Any ONE of the following:* [Note: Methyl propanoate is an ester.]

- as a fragrance
- as a flavour
- as a solvent
- for medicinal uses

(b) The high temperature used would cause some methanol to escape due to vaporisation. Refluxing with a water-cooled condenser prevents this loss, as it condenses any vapour formed, returning it to the reaction vessel.

(c) methanol 

propanoic acid 

72. (a) To heat water, $\Delta H = -mC\Delta T = -210 \times 10^{-3}\ \text{kg} \times 4.18 \times {}^{103}\ \text{J kg}^{-1}\ \text{K}^{-1} \times 65\ \text{K}$

$= 57{,}057\ \text{J} = 57.057\ \text{kJ}$

If 50% of heat released is lost to surroundings, energy required $= 57.057 \times 2\ \text{kJ}$

$\therefore$ moles ethanol required $= \frac{57.057 \times 2\ \text{kJ}}{1367\ \text{kJ mol}^{-1}} = 8.348 \times 10^{-2}\ \text{mol}$

Molar mass (ethanol), $M = (12.01 \times 2) + (1.008 \times 6) + (16.00 \times 6) = 46.068\ \text{g mol}^{-1}$

Moles ethanol burnt, $(n_{\text{ethanol}}) = \frac{m}{M} = 8.348 \times 10^{-2}\ \text{mol}$

$\therefore$ mass C_4H_9OH, $m = (8.348 \times 10^{-2}) \times 46.068 = 3.8458\ \text{g} = 3.8\ \text{g}$ *(to 2 sig figs)*

(b) *Any TWO of the following:*

- Surround the apparatus with a heat shield to minimise air drafts and reduce heat loss to the environment.
- Make sure the flame from the burning fuel is close to the container of water to reduce heat loss.
- Place a lid on the container to reduce heat loss from the water surface.

73. (a) $C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$

[Note: Combustion of butanol produces $H_2O(g)$. If asked for ΔH_c butanol equation, you would need to give $H_2O(l)$ … as (l) is the standard state.]

(b) Molar mass butan-1-ol, $C_4H_9OH = (4 \times 12.01) + (10 \times 1.008) + 16.00$

$= 74.12\ \text{g mol}^{-1}$

Fuel *A* has $\Delta H = -48 \times 74.12 = -3557.76\ \text{kJ mol}^{-1}$

Fuel *B* has $\Delta H = -38 \times 74.12 = -2816.56\ \text{kJ mol}^{-1}$

Fuel *C* has $\Delta H = -28 \times 74.12 = -2075.36\ \text{kJ mol}^{-1}$

Published ΔH(butan-1-ol) $= -2676\ \text{kJ mol}^{-1} = \frac{2676}{74.12} = 36.10\ \text{kJ g}^{-1}$

So only Fuel *C* has a lower value the published value for butan-1-ol, whereas Fuels A and B both have higher ΔH values.

In student experiments to determine enthalpy of combustion, a lot of heat usually escapes into the environment, resulting in a lower value being obtained than the published one.

74. (a) *Any ONE of the following:*

- Heat from the flame is lost into the surroundings.
- Experimental error in measuring the amount of ethanol used or in the amount of water, or in the temperature readings.
- The apparatus is also heated by the flame rather than just the water.

(b) $\Delta H = -mC\Delta T = 0.200 \times 4.18 \times 10^3 \times (45.0 - 21.0) = -20{,}064 \text{ J} = -20.064 \text{ kJ}$

Moles ethanol required, $n = \frac{-20{,}064}{1367} = 0.0147 \text{ mol}$

Molar mass (ethanol), $M = (12.01 \times 2) + (1.008 \times 6) + (16.00 \times 6) = 46.068 \text{ g mol}^{-1}$

$\therefore$ Mass of ethanol, $m = n_{\text{ethanol}} \times M_{\text{ethanol}} = 0.0147 \times 46.068$

$= 0.678 \text{ g}$ *(to 3 sig figs)*

75. (a) Hexene.

(b) POTENTIAL HAZARD: Using bromine water could become a problem, as bromine is highly toxic if inhaled, ingested or makes skin contact.

TO OVERCOME THIS PROBLEM: Safety goggles and gloves were worn and the experiment was performed in a fume cupboard.

(c) PROCEDURE: Equal quantities (~2 ml) of hexane and hexene were placed in separate test tubes. The same number of drops of Br water was added to each. They were shaken in the same way, in the absence of UV light (away from direct sunlight or fluorescent lights) and observed. An alkene (being unsaturated) will react more readily than an alkane (being saturated) with the Br water, so the sample that immediately decolourised the bromine water was recorded as hexene.

76. (a) Hydrogen [Note: $\frac{5460}{114} = 47.9 \text{ kJ g}^{-1}$; $\frac{10{,}000}{210} = 47.6 \text{ kJ g}^{-1}$; $\frac{285}{2} = 142 \text{ kJ g}^{-1}$; $\frac{1370}{46} = 29.8 \text{ kJ g}^{-1}$]

(b) $\text{density} = \frac{\text{mass}}{\text{volume}}$

$\therefore \text{mass of petrol} = 80 \text{ L} \times 1000 \text{ mL L}^{-1} \times 0.69 \text{ g mL}^{-1} = 55{,}200 \text{ g}$

$\text{moles of petrol} = \frac{55{,}200 \text{ g}}{114 \text{ g mol}^{-1}} = 484.2 \text{ mol}$

$\therefore \text{energy released} = 484.2 \text{ mol} \times 5460 \text{ kJ mol}^{-1} = 2{,}643{,}789.5 \text{ kJ} \approx 2.64 \times 10^6 \text{ kJ}$

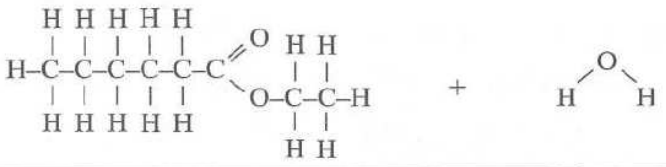
(c) $\text{Equivalent mol } H_2 = \frac{2{,}643{,}789.5 \text{ kJ}}{285 \text{ kJ mol}^{-1}} \text{ mol}$

$\therefore \text{volume of } H_2(g) = \frac{2{,}643{,}789.5 \text{ kJ}}{285 \text{ kJ mol}^{-1}} \times 24.79 \text{ L mol}^{-1} = 229{,}963 \text{ L} \approx 230 \text{ kL}$

77. Hexanoic acid and excess ethanol are refluxed together with a few drops of concentrated H_2SO_4 as a catalyst. To make it safer, boiling chips are also used to prevent 'bumping'.

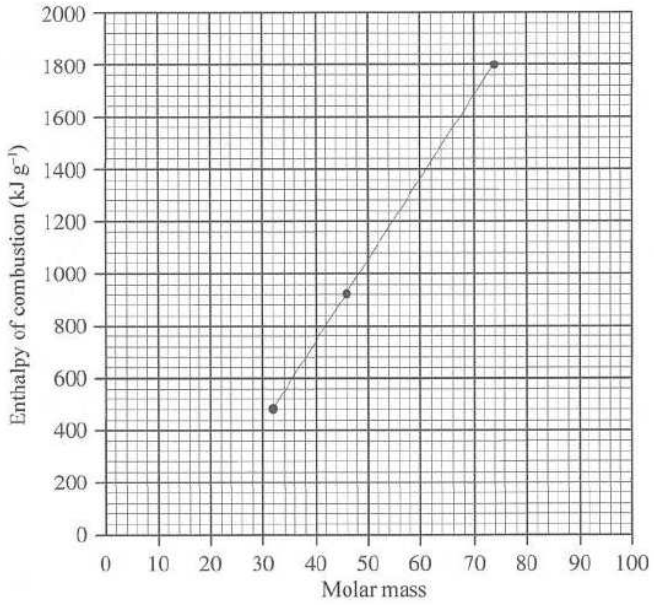
The products are:

ethyl hexanoate + water



78. 1,2–dichloro–1,1,2,2–tetrafluoroethane

79. (a)



[Note: Molar masses for the graph are:
methanol 32.042
ethanol 46.068
butan-1-ol 74.12]

(b) (i) Molar mass (propan-1-ol) = 60.1 g mol^{-1} $\therefore$ ΔH is 1360 kJ mol^{-1}

(ii) In practice, when combustion of a fuel occurs, water generally forms as a gas, whereas the theoretical value is calculated under standard conditions where water forms as a liquid and this would release more energy.

OR When combustion of propanol occurs, the combustion may be incomplete, producing carbon monoxide as well as carbon dioxide, and so the amount of energy released will be less.

80. (a) Detergent OR Anionic detergent

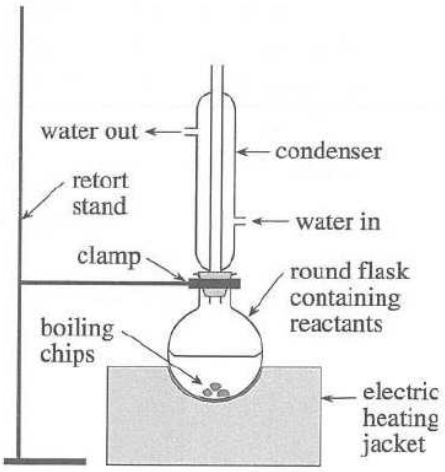
(b) A micelle is formed when the non-polar, hydrophobic hydrocarbon chains (the 'tail') of a detergent molecule mix with the oil/grease, while the polar, hydrophilic sulfonate ends ('heads') stick out away from the hydrophobic ends.

(b) When oil is added to water containing an anionic detergent, the hydrophobic ends of the detergent molecules mix with the oil and surround the oil droplets and the hydrophilic ends stick out of the droplets. Water molecules then join onto these projections and so an emulsion is formed. The polar ends immersed in the water are negatively charged and repel each other and prevent the oil droplets from recombining. This keeps the oil molecules suspended in the water as an emulsion.

81. Condensation polymerisation

82. (a) Butyl propanoate and water.

(b)



[Note: You must use an electric heating jacket and NOT a water bath – as the reaction mixture contains longer chain compounds with higher boiling points than water. A water bath would restrict the reaction mixture to a maximum of 100°C, and so there would be no reflux.]

(c) The reactants are volatile and if heated directly could ignite. The water-cooled condenser tube prevents the escape of volatile substances before they have reacted, as it causes them to be condensed and to drop back down to the reaction mixture for continued heating until they reach their activation energy. This allows the mixture to reach equilibrium.

83. (a) $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$

[Note: When a fuel such as ethanol is burnt, the water generally forms as a gas, as shown above. However, when the enthalpy of combustion is given with the equation, the value for the heat of combustion is determined for water in its standard state as a liquid:

$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) \quad \Delta H = -1360 \text{ kJ mol}^{-1}$]

(b) Molar mass (ethanol) = $(2 \times 12.01) + (6 \times 1.008) + 16.00 = 46.068$ g mol^{-1}

$n(C_2H_5OH) = \frac{72.5}{46.068} = 1.574$ mol

$n(CO_2) = 2 \times n(C_2H_5OH) = 2 \times (1.574) = 3.148$ mol

$\therefore$ volume of CO_2 (at 25°C, 100 kPa) = $3.148 \times 24.79 = 78.0$ L *(to 3 sig figs)*

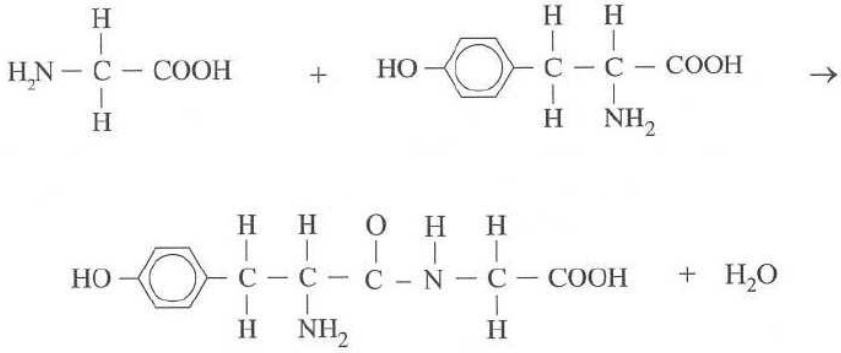
84. The chemical industry contributes greatly to the economy of a country. However, the industry often seeks to maximise profit and minimise expenses at the expense of the environment, e.g. chemical synthesis requires energy and most energy comes from the combustion of fossil fuels. This often results in unwanted drilled rocks from obtaining oil being returned into the ocean, thus contaminating it with Ba^{2+} ions from the lubricants used to increase the efficiency of drilling machines. Ba^{2+} ions are toxic as they interfere with enzyme activities in organisms. This can have social and economic implications as it reduces the yield of the fishing industry in affected oceans, and so result in poverty due to a reduced fishing income.

The oil industry makes a large profit from obtaining and processing hydrocarbons to make octane, which is used in petrol for cars. This industry generates employment, thus building a strong economy for countries where this takes place. However, the combustion of octane contributes to the enhanced greenhouse effect. The wastes generated can contaminate the environment, e.g. SO_2 and fertiliser run-off. These can lead to environmental problems, such as acid rain and eutrophication.

Hence it is important to consider and minimise the consequences from the process of obtaining hydrocarbons. The chemical industry needs to have measures that reduce or minimise hazardous chemicals and take environmental and social issues into account.

85. (a) protein

(b)



(c) A double bond between two carbon atoms, i.e. –C=C– bond

86. (a) $m\ (CO_2) = 381.05 - 370.39 = 10.66$ g

Molar mass $(CO_2) = 12.01 + 32 = 44.01$ g mol^{-1}

$\therefore\ n\ (CO_2) = \frac{10.66}{44.01} = 0.2422$ mol *(to 4 sig figs)*

(b) $C_6H_{12}O_6(aq) \xrightarrow{\text{zymase}} 2C_2H_5OH(aq) + 2CO_2(g)$

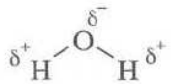
$n\ (C_6H_{12}O_6) = \frac{1}{2}\ n\ (CO_2) = 0.1211$ mol

Molar mass $(C_6H_{12}O_6) = (6 \times 12.01) + (12 \times 1.008) + (6 \times 16.00) = 180.156$ g mol^{-1}

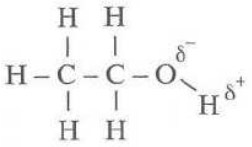
$\therefore$ Mass, $m\ (C_6H_{12}O_6) = 0.1211 \times 180.156 = 21.82$ g *(to 4 sig figs)*

87. Fossil fuels are being consumed at unsustainable rates and their supplies will soon become exhausted. Hence the need for alternative fuels, such as biofuels that are renewable and sustainable. To be sustainable, a biofuel must be able to be replenished at the same rate as it is consumed, and the wastes involved in making it must not harm the environment. Whereas fossil fuels are non-renewable, as they were produced over millions of years, and their limited reserves are being rapidly used up and cannot be replaced. The use of fossil fuels is not sustainable.

88. Water molecules are polar, since they have two –OH bonds that are angled. Hence water will dissolve most polar substances or substances containing –OH bonds including soluble salts, sugars, simple alcohols, etc, but will not dissolve non-polar substances such as hydrocarbons or esters/fats and oils.



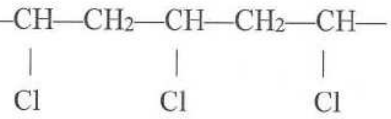
water



ethanol

As in water, the –OH end of ethanol molecules is polar and so hydrophilic. This makes ethanol a good solvent of polar substances, such as soluble salts, sugars as well as water, but not to the same extent as water. However, the other end is a non-polar, short hydrocarbon chain that is hydrophobic. This end enables ethanol to also dissolve many non-polar materials, such as hydrocarbons and many other organic materials.

89. (a)



(b) Monomer is vinyl chloride. IUPAC name is chloroethene.
Polymer is polyvinyl chloride

(c) Addition polymerisation – the monomer must have a double bond present between two carbon atoms.

(d) Low density polyethylene (LDPE) – this has a long chain with significant branching, which prevents the chains packing closely together. The weak dispersion forces between the chains gives them a low density and low melting point. This results in them being soft and flexible. Hence LDPE can be moulded into soft, squeezable containers for soft drinks, etc as well as plastic bags, cling wrap, etc

High density polyethylene (HDPE) – this has long, unbranched molecules that can be packed closely together. Hence they have a higher density. They have stronger dispersion forces between the chains and a higher melting point. This results in them being hard, but with greater flexibility. Hence HDPE can be moulded into stronger, more durable containers that hold their shape, e.g. used for petrol, acids and solvents, as well as kitchen utensils, rubbish bins, water pipes, etc

90. Their similar physical properties (e.g. density, melting point) depend on the intermolecular forces, which are not very different. Both have non-polar molecules. An alkane has only two more H atoms than the corresponding alkene.

Their chemical properties differ because alkenes have a C=C double bond that can undergo addition reactions, whereas an alkane only has C–C bonds that are relatively unreactive. When an alkane reacts, atoms must break away from the parent molecule, and other atoms substitute for them.

