Name:	Target Grade:	Actual Grade:

BRIGHT CULTURE

ORGANIC CHEMISTRY
MCQ and STRUCTURED QUESTIONS

READ THESE INSTRUCTIONS FIRST

INSTRUCTIONS TO CANDIDATES

1. Find a quiet, comfortable spot free place from distractions.

2. Spend one minute on each mark.

3. Time yourself for every single question.

4. Every chapter has their own question types. Ensure that you know the different question type for each chapter.

5. Make a conscientious effort to remember your mistakes, especially in terms of answering techniques. E.g Take a picture for the mistakes that you made, keep it in a photo album, and revise it over and over again.

6. Highlight question types that you tend to keep making mistakes and review them nearing exams.

7. Always review the common questions and question type that you tend to make mistakes nearing exams.

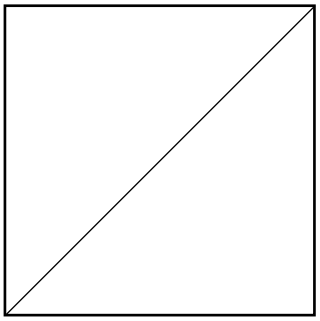
8. During exams, classify the question type and recall what you have learnt, how you need to analyse the questions for the different question type, what you need to take note of and answer with the correct answering techniques!

✨ **Wishing you all the best for this test!**

You've got this!

💡 **With lots of love,**
Bright Culture 💛

MARKS



If you are struggling in this paper, means you need to work harder!

If you need any professional guidance and further advice on how to advance, feel free to WhatsApp us at 91870820 or find us at www.bright-culture.com/. We are committed to connect you to your future to reach your goals.

ORGANIC CHEMISTRY MCQ

Paper 1

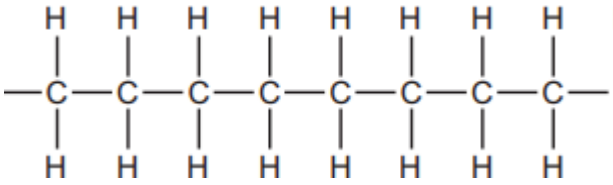
1. The table shows the energy released by complete combustion of some compounds used as fuels.

compound	Mr	I\H (kJ/mo)
methane	16	-880
ethanol	46	-1380
propane	44	-2200
heptane	100	-4800

Which fuel produces the least energy when 1 g of the compound is completely burned?

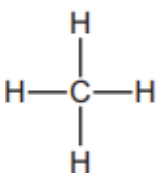
A methane
B ethanol
C propane
D heptane

2. The diagram shows part of the molecule of a polymer.



Which diagram shows the monomer from which this polymer could be manufactured?

A



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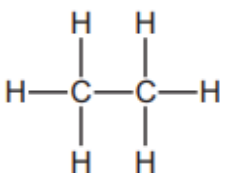

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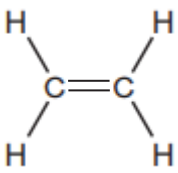

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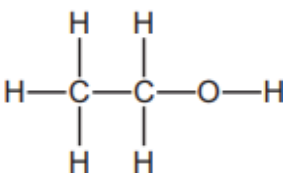


3. Which compound will react with steam, in the presence of catalyst, to produce the alcohol $CH_3CH_2CH_2OH$?

A CH_3CHCH_2
B $CH_3CHCHCH_3$
C $CH_3CH_2CH_2CH_3$
D CH_3CH_2COOH

4. Which type of reaction does this equation show?

$$C_3H_8 + F_2 \rightarrow C_3H_7F + HF$$

A Hydration
B Neutralisation
C Addition
D Substitution

5. An unsaturated hydrocarbon with six carbon atoms contains only three C=C double bonds. This hydrocarbon is reacted with excess bromine at a room temperature.

What is the formula of the resulting hydrocarbon?

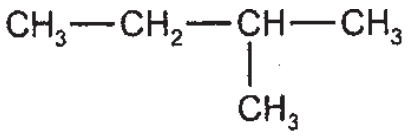
A $C_6H_8Br_3$
B $C_6H_{10}Br_3$
C $C_6H_8Br_6$
D C_6H_{14}

6. A hydrocarbon is found to contain about 80% of carbon by mass. What is the hydrocarbon?

A Methane
B Ethene
C Propane
D Hexene

7. Which structure is not an isomer of the structure shown?

A



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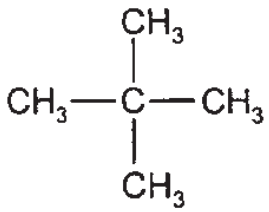

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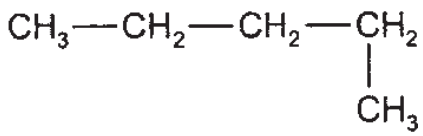

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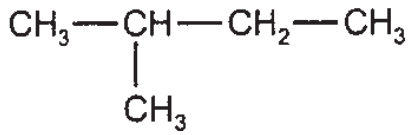
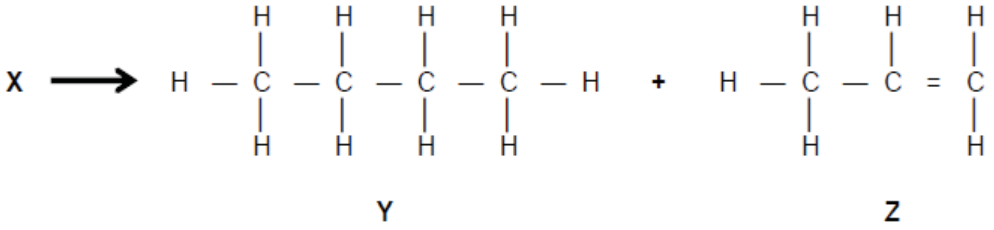


8. Some unsaturated compounds contain more than one carbon-carbon double bond. An example is the compound with the formula $C_{21}H_{26}$.

How many carbon-carbon double bonds are present in one molecule of this compound?

A 3
B 5
C 8
D 9

9. A chemist carried out a cracking reaction on a hydrocarbon, **X** and obtained two products, **Y** and **Z**.



The chemist then wrote the following statements in his notebook.

(1) A molecule of **X** has 7 carbon atoms.
(2) **Y** is unsaturated.
(3) **Z** will decolourise bromine water.

Which statement(s) is/are correct?

A (3) only
B (1) and (2)
C (1) and (3)
D (1), (2) and (3)

10 The table shows the boiling points of four fractions when crude oil is distilled.

fraction	W	X	Y	Z
boiling point /°C	35 - 75	80 - 145	150 - 250	greater than 250

Which statement regarding the fractions is true?

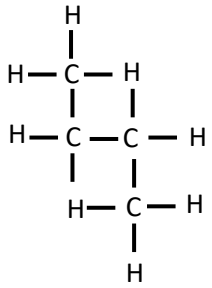
A Fraction W is more flammable than fraction Y.
B Fraction W is more viscous than fraction Z
C The density of fraction X is greater than that of fraction Z.
D The molecules in X have a longer chain length than those in fraction Z.

11 1 mole of a compound X reacts completely with 2 moles of hydrogen gas in the presence of a catalyst to form 1 mole of alkane.

Which compound could X be?

A $CH_2=CH-CH=CH-CH=CH_2$
B $CH_2=CH-CH_2-CH_2-CH=CH_2$
C $CH_2=CH-CH_2-CH_2-CH_2-CH_3$
D $CH_2=CH-CH_2-CH_2-COH=CH_2$

12 Which of these molecules have the same boiling points?



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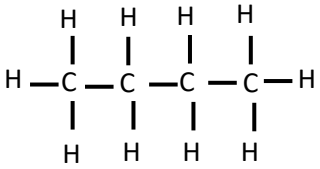
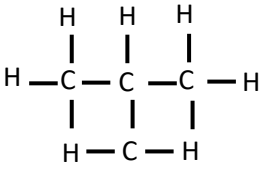


Q



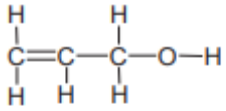
R

A P and Q
B P and R
C Q and R
D P, Q and R

13 An organic compound S has the following reactions:

- neutralises sodium hydroxide
- decolourises aqueous bromine

Which structure represents S?

A


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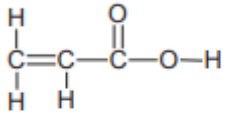

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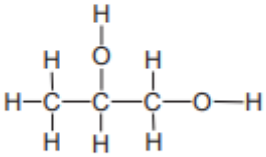

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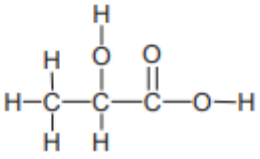
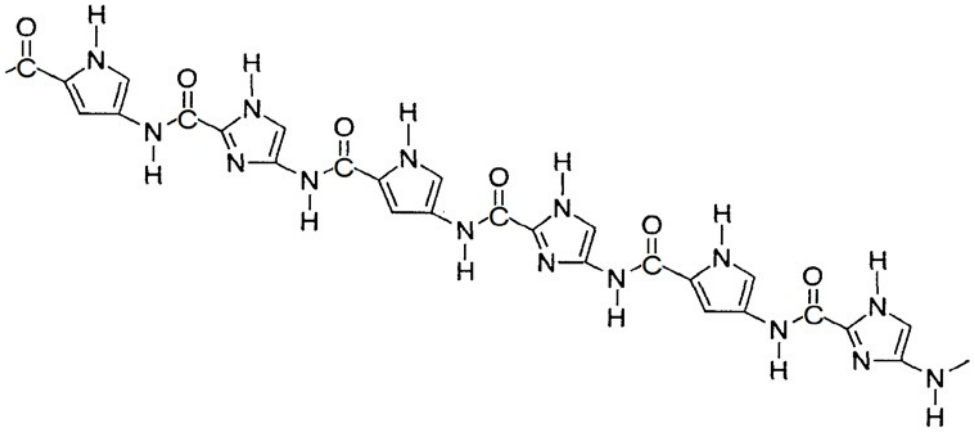


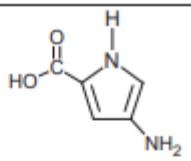
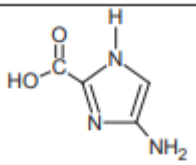
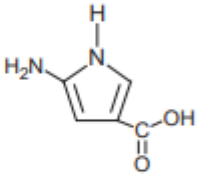
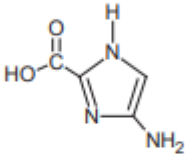
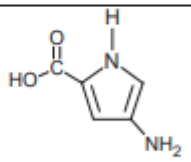
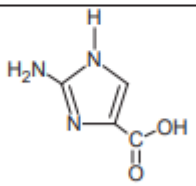
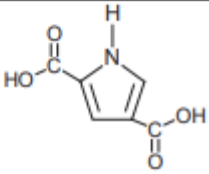
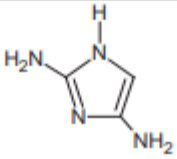
14 Which statement describes the property of the first fraction obtained from the fractional distillation of crude oil?

A It gives the most sooty flame when burnt.
B It has the highest boiling point.
C It is the most miscible with organic solvent.
D It is the most viscous.

15 The structure below shows part of a polymer.



Which option shows the correct monomers?

	monomer 1	monomer 2
A		
B		
C		
D		

16 The compound, C_8H_{18} undergoes the following process.

$$C_8H_{18} \xrightarrow{\text{Process X}} \text{Ethene + Compound Y}$$

Which row in the table correctly identifies Process X and Compound Y?

	Process X	Compound Y
A	cracking	hexane
B	cracking	hexene
C	distillation	hexane
D	distillation	hexene

17 How many moles of hydrogen chloride are formed when one mole of methane is added to a large excess of chlorine in the dark?

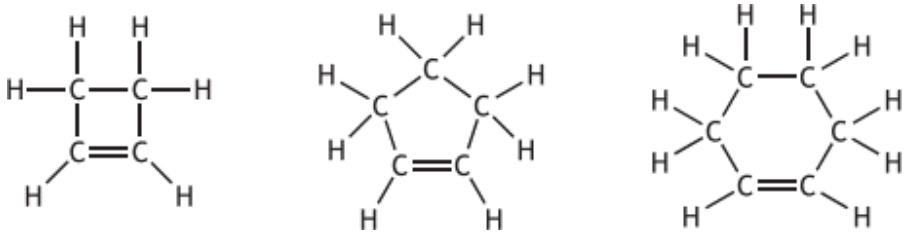
A 0

B 1

C 2

D 4

18 Three members of the cycloalkene homologous series are shown:



Which of the following is the general formula for this homologous series?

A C_nH_{2n-4}

B C_nH_{2n-2}

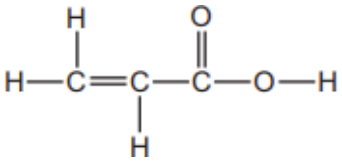
C C_nH_{2n}

D C_nH2_{n+2}

19 Oil contains carbon-carbon double bonds which can undergo addition reactions with iodine. The iodine number of an oil is the mass of iodine in grams that will react with 100 g of oil.
Which row in the table shows the oil that is likely to have the lowest melting point?

	oil	iodine number
A	corn	123
B	linseed	179
C	olive	81
D	soya	130

20 A compound has the following structure.



Which reaction(s) will occur with this compound?

1 Bromine water will decolourise.
2 It will react with an alcohol to form an ester.
3 It will react with sodium metal.

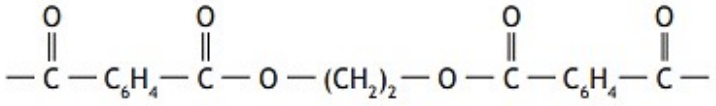
A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

21 Polyvinyl chloride (PVC) is a man-made polymer used mainly in the manufacture of pipes. PVC pipes are strong, lightweight and does not rot.
Which statements correctly describe the polymer, polyvinyl chloride, PVC?

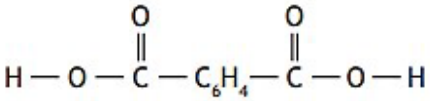
1 Combustion of PVC waste produces a highly acidic gas.
2 PVC molecules are saturated.
3 The empirical formula of PVC is the same as the empirical formula of its monomers.

A 1 and 2 only
B 1 and 3 only
C 2 and 3 only
D 1, 2 and 3

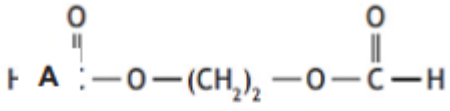
22 A section of a condensation polymer is shown below.

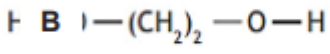


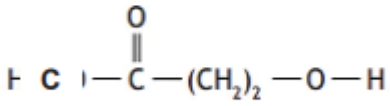
One of the monomers is

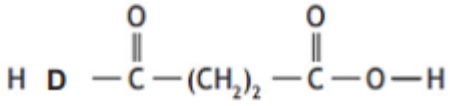


The structural formula of the other monomer is

A 

B 

C 

D 

23 Which statement(s) best explains why bitumen has a higher boiling point than paraffin?

1 Bitumen is more reactive than paraffin.
2 Bitumen is a pure substance whereas paraffin is a mixture.
3 Forces of attraction between the molecules of paraffin are weaker than that between the molecules of bitumen.
4 There are smaller molecules in bitumen compared to the molecules in paraffin.

A 1 and 2
B 1, 2 and 3
C 3 only
D 3 and 4

24 Which compound is the most viscous and the least flammable?

A C_6H_{14}
B C_8H_{18}
C $C_{10}H_{22}$
D $C_{12}H_{26}$

25 The second member of a homologous series has the formula C_7H_8.

What is the formula of the first member?

A C_6H_6
B C_6H_8
C C_6H_7
D C_7H_6

26 An ester is produced by reacting together the carboxylic acid HCO_2H and the alcohol $CH_3CH_2CH_2OH$.

What is the name and structure of this ester?

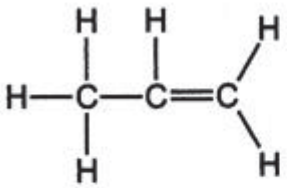
	name	structure
A	methyl propanoate	$CH_3CH_2CO_2CH_3$
B	methyl propanoate	$HCO_2CH_2CH_2CH_3$
C	propyl methanoate	$CH_3CH_2CO_2CH_3$
D	propyl methanoate	$HCO_2CH_2CH_2CH_3$

27 Compound Y

- has the empirical formula CH_2,
- has an M_r of 56,
- forms two alcohols that have different structural formulae when reacted with steam.

What is compound Y?

A



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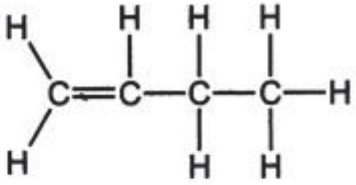

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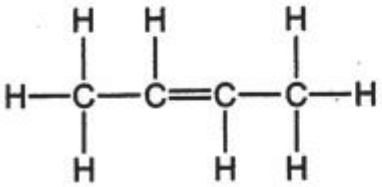

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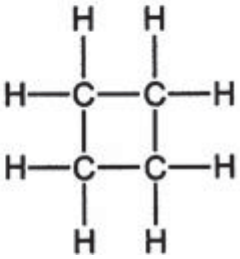
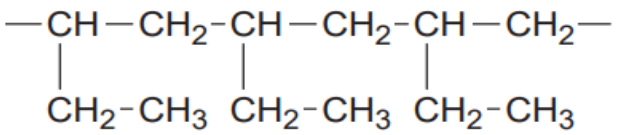


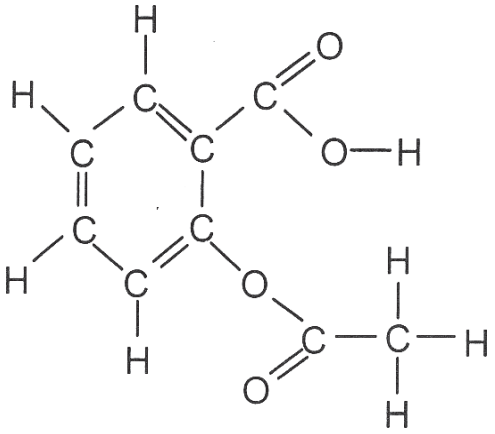
28 The structure of a polymer is shown below.



What is the molecular formula of the monomer?

A C_2H_4
B C_3H_8
C C_4H_8
D C_4H_{10}

29 Aspirin is a drug which is used as a general pain killer. The structural formula of aspirin is shown below.



Which of the following statements about aspirin is **false**?

A Its aqueous solution reacts with sodium carbonate.
B It decolourised aqueous bromine.
C It is formed from an alcohol and a carboxylic acid.
D It turns purple acidified aqueous potassium manganate (VII) colourless.

30 The diagrams show four monomers.

How many of these monomers would react with the molecule below to form a polymer?

A 1
B 2
C 3
D 4

31 The enthalpy change for the complete combustion of three different fuels, methane, ethanol and propene are as shown below.

fuel	formula	M_r	enthalpy change of combustion / kJ/mol
methane	CH_4	16	-100
ethanol	C_2H_5OH	46	-75
propene	C_3H_6	42	-170

What is the correct order of fuels, starting from the fuel that provides the most energy per gram of fuel, when the fuel undergoes complete combustion?

A methane, propene, ethanol
B methane, ethanol, propene
C propene, methane, ethanol
D ethanol, propene, methane

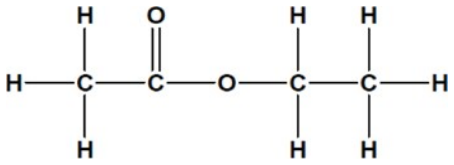
32 The table shows the boiling points of four fractions, P, Q, R and S, obtained when crude oil is distilled.

Fraction	P	Q	R	S
Boiling Range / °C	35-75	80-145	150-250	greater than 250

How is fraction P different from S?

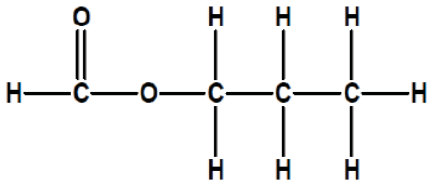
A Fraction P is more viscous than fraction S.
B Fraction P is in less demand than fraction S.
C Fraction P is more flammable than fraction S.
D Fraction P contains molecules of larger molecular masses than fraction S.

33 The diagram shows the structure of ethyl ethanoate.

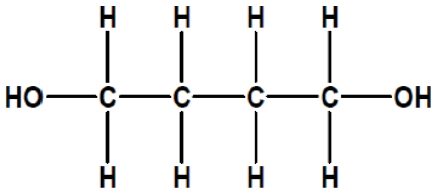


Which structure is **not** an isomer of ethyl ethanoate?

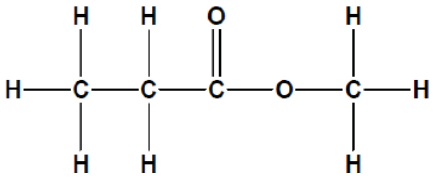
A



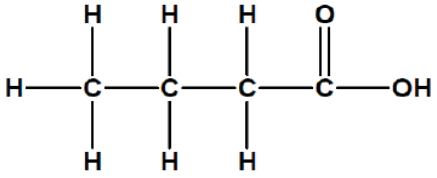
B



C



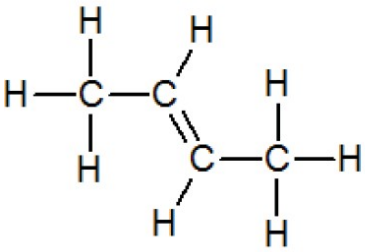
D



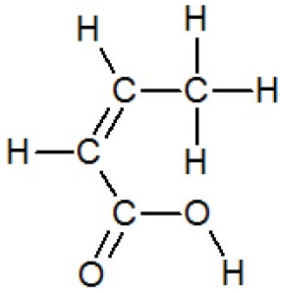
34 60 cm^3 of oxygen was mixed with 10 cm^3 of gaseous hydrocarbon in a closed vessel. After explosion and cooling, the gases occupied 50 cm^3 and after passing the gas through aqueous sodium hydroxide, 30 cm^3 of oxygen remained. Deduce the molecular formula of the hydrocarbon.

A CH_4
B C_2H_4
C C_2H_6
D C_3H_6

35 The full structural formulae of compounds X and Y are shown below.



Compound **X**



Compound **Y**

The **best** method to distinguish between X and Y visually is by using

A aqueous bromine
B potassium hydroxide solution
C potassium carbonate solution
D acidified potassium manganate(VII) solution

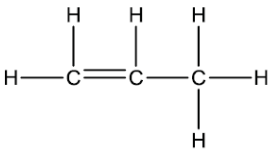
36 A food chemist wants to create the odour of pineapples for a product. An ester with this odour has the formula $C_3H_7CO_2C_4H_9$.

Which pair of substances will react to produce this ester?

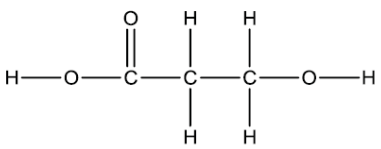
A $C_2H_5CO_2H$ and C_4H_9OH
B $C_2H_5CO_2H$ and C_3H_7OH
C $C_4H_9CO_2H$ and C_3H_7OH
D $C_3H_7CO_2H$ and C_4H_9OH

37 Which compounds would undergo polymerisation on their own?

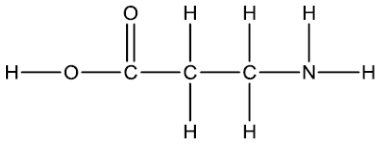
1



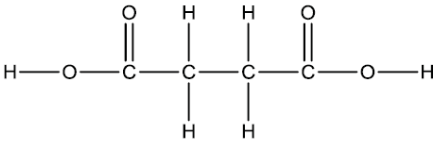
2



3

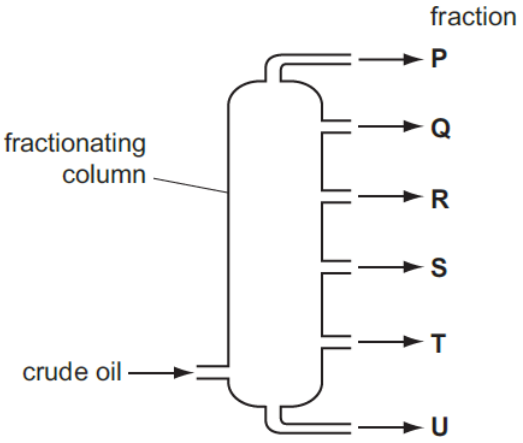


4



A 1 and 2 only
B 2 and 3 only
C 1, 2 and 3 only
D 1, 2, 3 and 4

38 The diagram shows the fractional distillation of crude oil.



Which statement is correct?

A Each fraction consists of a single compound.

B Fraction P has the highest boiling point.

C The highest temperature is at the top of the column.

D The naphtha fraction is used as feedstock for the chemical industry.

39 Which property of a liquid ester can be used to check its purity before use as a food flavouring?

A boiling point
B smell
C colour
D smell

40 Which compound is the most viscous and the least flammable?

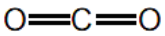
A C_6H_{14}

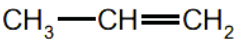
B C_8H_{18}

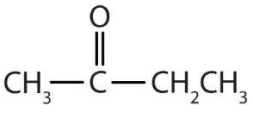
C $C_{10}H_{22}$

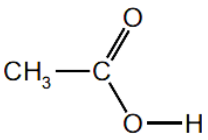
D $C_{12}H_{26}$

41 How many of the following structures show an unsaturated hydrocarbon molecule?









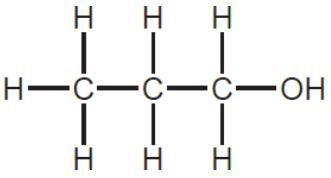
A 1

B 2

C 3

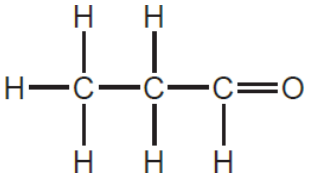
D 4

42 This is the structural of propan-1-ol.

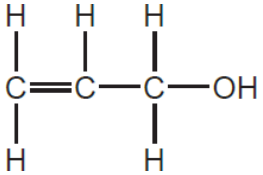


Which of the following is an isomer of propan-1-ol?

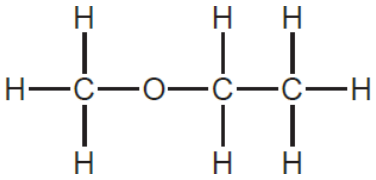
A



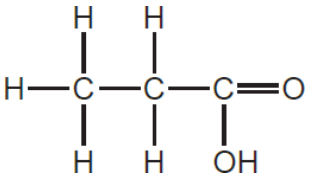
C



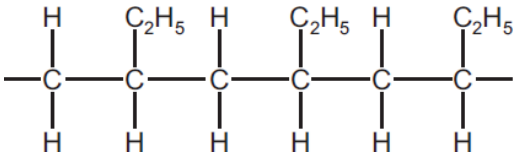
B



D



43 The diagram shows a section of a polymer.



Which alkene is used to make this polymer?

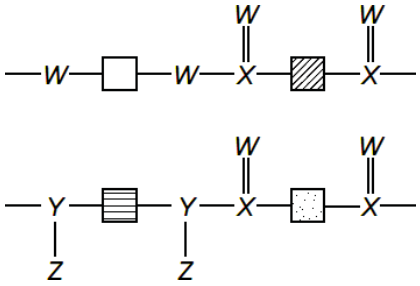
A $CH_3CH=CH_2$

B $CH_3CH_2CH=CH_2$

C $CH_3CH_2CH=CHCH_2$

D $CH_3CH=CHCH_3$

44 The diagram shows the partial structures of two different polymers.



Which chemical symbols should replace *W*, *X*, *Y* and *Z*?

	W	*X*	*Y*	*Z*
A	C	N	H	O
B	N	H	O	C
C	O	C	H	N
D	O	C	N	H

Organic Chemistry: Hydrocarbon as fuels

45 Octane is an alkane found in petrol.
Which statement about octane is correct?

A It can be polymerised.
B It decolourises aqueous bromine.
C It has a lower boiling point than methane.
D It reacts with chlorine by substitution.

46 Which statement about a petroleum fraction is correct?

A It boils at a fixed temperature.
B Its molecules are all hydrocarbons.
C None of its molecules is found in other fractions,
D Its molecules all contain the same number of carbon atoms.

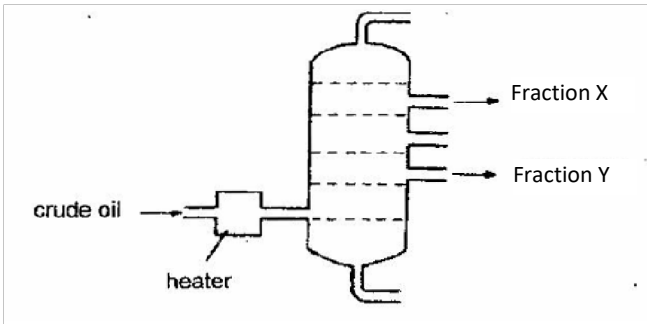
47 Rubber is a hydrocarbon. A tyre for a bus is made by heating together a mixture of rubber and sulfur. What are all the possible products if a piece of the tyre is burnt in air?

A Carbon monoxide, carbon dioxide and water.
B Carbon monoxide, soot and sulfur dioxide.
C Soot, carbon monoxide, carbon dioxide and water.
D Carbon dioxide, carbon monoxide, soot, water and sulfur dioxide.

48 Leaded petrol contains tetraethyllead, $Pb(C_2H_5)_4$. Which of the following is not produced from the combustion of tetraethyllead?

A carbon monoxide
B nitrogen monoxide
C lead(II) oxide
D water vapour

49 The diagram shows the fractional distillation of crude oil.



Which statements about the fractions **X** and **Y** are correct?

	X is more flammable than **Y**	**X** has a higher boiling point than **Y**	**X** is more viscous than **Y**
A	Yes	No	No
B	Yes	Yes	No
C	No	Yes	Yes
D	No	No	Yes

50 When crude oil is distilled, a number of fractions are collected. Which of these statements about the fractions is true?

A The first fraction has the lightest colour.
B The first fraction is a single pure substance.
C The first fraction burns with a lot more soot than last fraction.
D The first fraction has the highest boiling point.

51 Which statement about 'fossil fuel' is true?

I They contain carbon.
II They are renewable.
III They are all in liquid form.
IV They are all made from remains of the ancient trees and plants millions of years ago.

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

52 Which of the following petroleum fractions is correctly matched with its application?

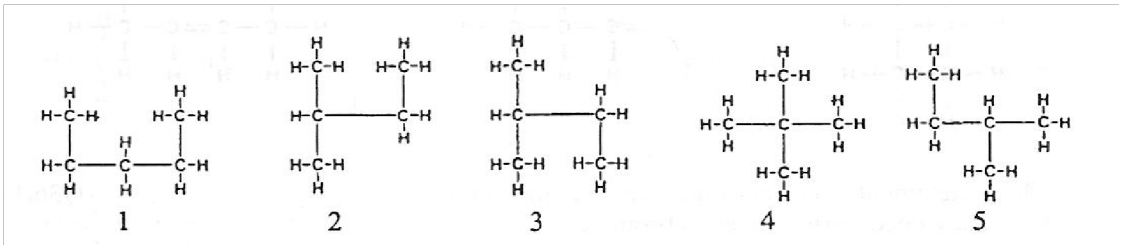
	Fraction	Application
A	naphtha	chemical feedstock
B	bitumen	waxes and polishes
C	kerosene	surfacing roads
D	lubricating oil	fuel for aircraft

53 Which substance, present in car exhaust fumes, is not produced by the combustion of hydrocarbons?

A water vapour
B oxides of nitrogen
C carbon dioxide
D carbon monoxide

Organic Chemistry: Alkane

54 Five structural formulae are shown below.



Which of the following represents 3 different isomeric compounds?

A 1, 2 and 4
B 2, 3 and 4
C 2, 3 and 5
D 1, 2 and 3

ORGANIC CHEMISTRY STRUCTURED QUESTIONS

Paper 2 Section A

1. An alcohol **G** was known to be one of the following.

HOHOCHCH=CHCHOHOH Alcohol **1**

$CH_3CH_2CH_2CH_2OH$ Alcohol **2**

A sample of 1.20 g of alcohol **G** was burned in excess oxygen. 1.79 g of carbon dioxide was formed.

(a) Calculate the mass of carbon present in the sample of alcohol **G**. [1]

(b) The mass of hydrogen in the sample is 0.0812 g. Assuming that the rest of the sample is oxygen, calculate the mass of oxygen in the sample. [1]

(c) Use your answers above to find the empirical formula of alcohol **G**. [2]

(d) State the identity of alcohol **G**. Explain clearly how you reached this conclusion. [1]

……..

……..

……..

……..

(e) Describe a chemical test to distinguish between alcohol **1** and alcohol **2**. Include expected results in your answer. [1]

……..

……..

……..

……..

(f) Propene can be converted into an alcohol.

Show the **structural equation** for the above reaction. [2]

[Total: 8]

2 The table shows some information about a homologous series of organic compounds called ketones.

name	number of carbon atoms	formula
propanone	3	CH_3COCH_3
butanone	4	$C_2H_5COCH_3$
pentanone	5	$C_3H_7COCH_3$

(a) Deduce the name and formula of the ketone that contains 6 carbon atoms. [2]

name ……

formula ……

(a) From **(a)**, deduce the general formula for ketones.

……[1]

(b) The oxygen atom in a ketone forms a double bond with a carbon atom. Draw the full structural formula of butanone.

[1]

(c) Separate samples of propanone and propene were placed in separate test tubes and each shaken with bromine water.

Predict what will be seen in each test tube after shaken with bromine water.

……...

……...

……..[2]

[Total: 6 marks]

Paper 2 Section B

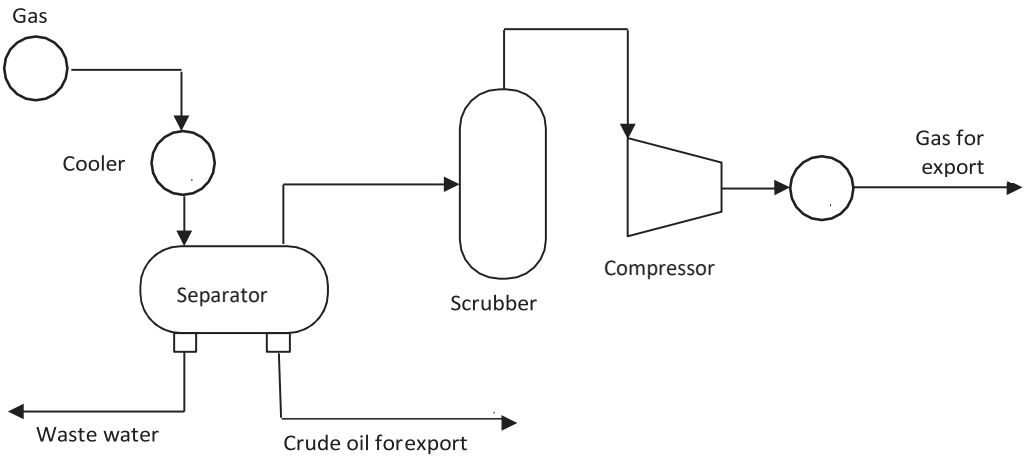
1. Natural gas is a mixture of hydrocarbon compounds formed from the remains of dead plants and animals over a long period of time. It is often found together with other fossil fuels such as crude oil.

An example of components of natural gas is shown in the table.

name	formula	percentage composition / %	boiling point / °C	liquid density / g/cm^3
methane	CH_4	70	- 162	0.423
ethane	C_2H_6	10	- 89	0.546
propane	C_3H_8	10	- 42	0.493
others (carbon dioxide, hydrogen sulfide, etc.)	-	10	-	-

Adapted from: www.naturalgas.org

Natural gas that is extracted from the ground must be purified before it can be used. A simplified diagram showing the process of purification is given in the diagram below. The first step is to cool the mixture and remove water and other dense components like crude oil. The raw gas is then sent to a series of scrubbers, compressors and coolers. Finally, the gas is either compressed or liquefied, and then exported.



Compressed natural gas (CNG) is compressed to 200 to 250 times atmospheric pressure, such that it occupies about 1% of the volume it would otherwise have occupied, and stored in high-pressure tanks. Liquefied natural gas (LNG) is cooled to about -170°C, where it occupies about 1/600th of the volume it would otherwise have occupied, and stored in special insulated tanks.

(a) **(i)** What is the main component of natural gas?

…… [1]

(ii) Draw a dot and cross diagram to show the bonding of one molecule of the main component of natural gas stated in **(a) (i).**
You only need to show the outer shell electrons.

[2]

(iii) Explain, using ideas about bonding and structure, why natural gas is volatile.

……

……

……

……

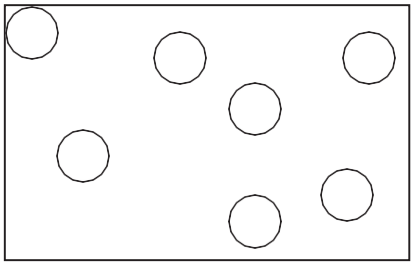
……

…… [2]

(b) Name a piece of apparatus found in the school laboratory which functions on the similar principle as the separator shown in the diagram.

…… [1]

(c) **(i)** The diagram shows the arrangement of particles in natural gas at room temperature and pressure. Draw similar diagrams to show the arrangement of the same number of particles in liquefied natural gas (LNG) and compressed natural gas (CNG).



LNG **CNG**

[2]

(ii) Using the information given, suggest **one** advantage of using liquefied natural gas (LNG) over compressed natural gas (CNG).

……

……

……

……

……

…… [2]

[Total: 10]

2 The investigation of hydrocarbons

Information 1

From its modest beginning in 1980, the U.S. ethanol industry has grown tremendously in response to surging domestic use and worldwide demand.

The table below shows two different identified processes to produce ethanol.

Process 1	Process 2
Fermentation of a sugar solution by yeast in a reaction vessel. The reaction vessel has to be emptied, cleaned and refilled every few days. The process produces a 15% ethanol solution in water daily.	Reaction of ethene (from crude oil) with steam in a reactor. The reaction is only stopped if there is a fault in the reactor. The process produces 100% pure ethanol.

Information 2

An advertisement for crisps claimed that they are healthier because they are cooked in certain oils. A student found the following information about four oils that are used to make crisps.

	Rapeseed oil	Sunflower oil	Olive oil	Corn oil
Saturated fat / %	6.6	12.0	14.2	14.4
Poly- unsaturated fat / %	29.3	63.3	8.1	51.3
Melting point / ^oC	+5	-18	-12	-15

One hypothesis is that oils are thought to be healthier if they are:

- Low in saturated fat.
- High in poly-unsaturated fat.

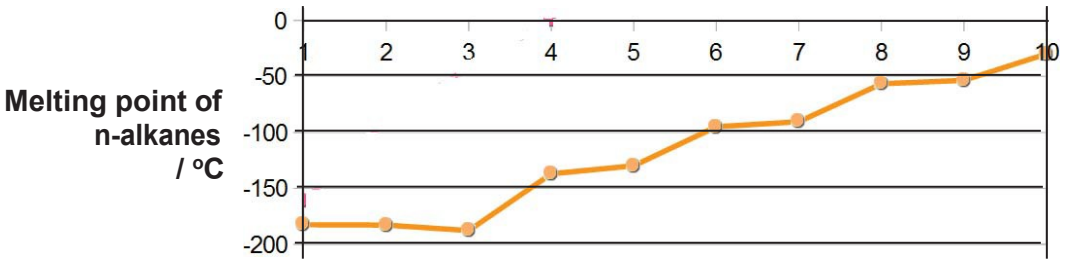
For certain oils and fats such as olive oil, soybean oil, or nut oils, when compared with others, such as margarine, butter, chicken fat and beef fat (the white stuff found in and around slabs of meat), the most prominent difference that was discovered was that different oils and fats have different states of matter at room temperature.

Some oils and fats are liquid at room temperature, and even when kept in the fridge, like olive oil and soybean oil. By contrast, other fats have higher melting temperatures.

The melting point of fats is the temperature at which they become liquid. **Graph 1** shows the change in melting point for saturated hydrocarbon.

Graph 1

Melting point of n-alkanes



The melting temperature is the same as freezing temperature; it is the temperature where the fat changes from a liquid to a solid.

In addition, the effect of the percentage of saturated fats within certain oils on the energy released from combustion was investigated. It was found out that as the saturation of the carbon chain increases, the energy released from combustion decreases.

Table 1: Experimental results on the four different oil used

		Rapeseed oil	Sunflower oil	Olive oil	Corn oil
Energy released from combustion (kJ/g)	Trial 1	5.05	3.48	6.55	3.95
	Trial 2	4.98	3.20	5.98	2.01
	Trial 3	4.46	2.98	6.24	3.88

Table 2: Hydrocarbon table

Name	Chemical formula	Heat of combustion (kJ/g)
Methane	CH_4	55.6
Ethane	C_2H_6	52.0
Propane	C_3H_8	50.0
Butane	C_4H_{10}	49.2

Note: Heat of combustion is also known as enthalpy change. It refers to the heat energy released when a compound undergoes complete combustion with oxygen under a given condition.

(a) Using **Information 1**,

(i) Give one advantage that Process 1 has over Process 2. [1]

……

……

(ii) State one advantage Process 2 has over Process 1 as a manufacturer of ethanol. [2]

……

……

……

(b) Using **Information 2,**

(i) Determine which oil should be helathier.

Explain your answer.

……

……

……

(ii) These unsaturated oils can be hardened by an addition reaction with hydrogen at 200 °C with nickel catalyst. [2]

A student said that this hardening process would make sunflower oil healthier.

Is this student's hypothesis correct? Explain your answer.

……

……

……

(iii) Using **Table 2**, describe and explain the data patterns for series of heat of combustion on the different alkanes. [2]

……

……

……

(iv) Based on the information given, describe the trend of the melting point of alkanes. [1]

……

[Total: 10]

3 Petroleum is a source of many important chemicals.

(a) Name **two** industrial processes which must take place to produce alkenes from petroleum.

……[2]

(b) Ethene and propene can both be converted into polymers.

(i) State the type of polymerisation that takes place when ethene forms a polymer.

……[1]

(ii) Identify the empirical formula of the polymer formed from ethene.

……[1]

(iii) Draw **two** repeat units of the polymer made from propene. [2]

(c) Most of the hydrocarbons obtained from petroleum are alkanes. The alkanes are homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}.

Give two characteristics, other than having the same general formula, of members in the same homologous series.

……

……

(d) When one mole of chlorine, Cl_2, reacts with one mole of propane, a mixture of **two** structural isomers is formed in the **first step** of substitution.

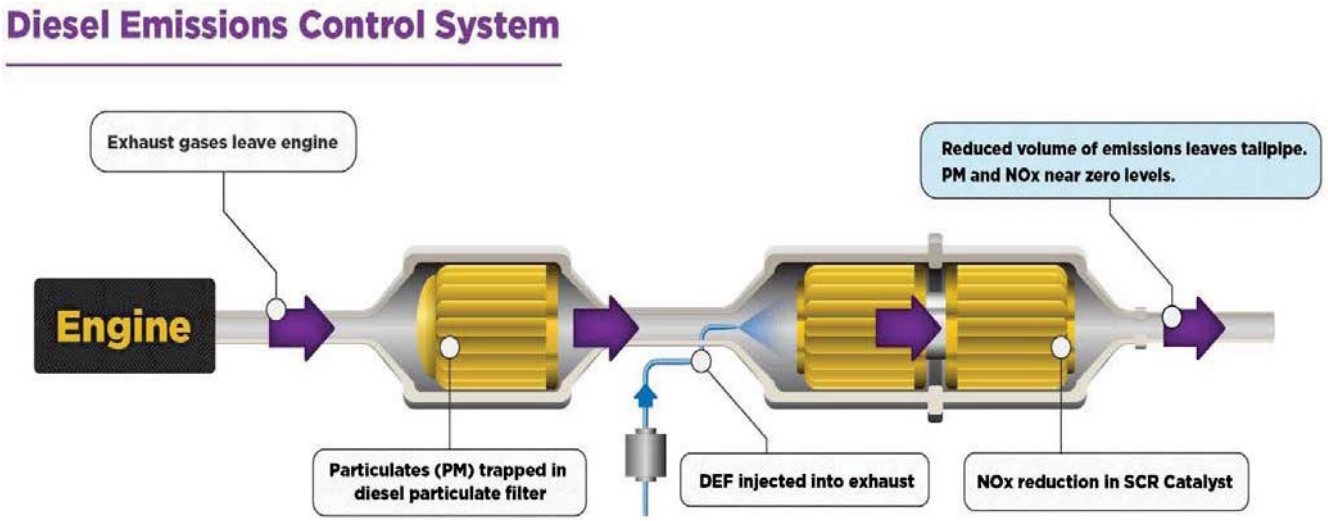
Draw **all** the structural formulas of the isomers formed when one mole of chlorine reacts with one mole of propane. [2]

[Total: 10]

4 Diesel engines can be run with a lean burn air-to-fuel ratio which is larger than that in petrol engine, This is to ensure the full combustion of soot and to prevent them from giving out unburnt fuel. This then leads to generation of oxides of nitrogen (NO_x), which are harmful pollutants, from the nitrogen and oxygen in the air.

Introduction to Diesel Exhaust Fluid (DEF)
Diesel exhaust fluid (DEF) is an aqueous urea solution made with 32.5% by mass of urea, $(NH_2)_2CO$, and 67.5% by mass of deionised water. It is called AUS 32 (aqueous urea solution).

DEF is used in selective catalytic reduction (SCR) in order to lower the concentration of NO_x in the diesel exhaust emissions from diesel engines. Within the SCR catalyst, the NO_x are catalytically reduced by ammonia into water and nitrogen, which are both harmless. These are then released through the exhaust.



Source: http://www.dieselforum.org/about-clean-diesel/what-is-scr

Selective Catalytic Reduction (SCR) systems
SCR catalysts are made from various ceramic materials used as a carrier, such as titanium oxide, and active catalytic components are usually oxides of base metals such as vanadium, molybdenum and tungsten.

The two most common designs of SCR catalyst geometry used today are honeycomb and plate. Each design has different advantages and disadvantages.

	plate-type	honeycomb-type
pressure drop	lower	larger
plugging and fouling	less susceptible	more susceptible
size	large and bulky	smaller
price	expensive	relatively cheaper

**'Plugging and fouling' causes the catalyst to be coated with a layer of unwanted material.*

Reduction of oxides of nitrogen (NO_x)
DEF from a separate tank is injected into the exhaust pipeline. When it is injected into the hot exhaust gas stream, the water evaporates and the urea thermally decomposes to form ammonia and isocyanic acid:

$$(NH_2)2CO(g) \rightarrow NH_3(g) + HNCO(g)$$

The isocyanic acid hydrolyses to carbon dioxide and ammonia:

$$HNCO(g) + H_2O(g) \rightarrow CO_2(g) + NH_3(g)$$

Overall reaction:

$$(NH_2)2CO(g) + H_2O(g) \rightarrow 2NH_3(g) + CO_2(g)$$

From this point, ammonia, in the presence of oxygen and a catalyst, will reduce oxides of nitrogen:

$$2NO(g) + 2NH_3(g) + \frac{1}{2}O_2(g) \rightarrow 2N_2(g) + 3H_2O(g) \text{ and}$$

$$3NO_2(g) + 4NH_3(g) \rightarrow \frac{7}{2}N_2(g) + 6H_2O(g)$$

The overall reduction of nitrogen monoxide by urea is:

$$2(NH_2)2CO(g) + 4NO(g) + O_2(g) \rightarrow 4N_2(g) + 4H_2O(g) + 2CO_2(g)$$

DEF is injected into the exhaust gas at 2–6% of diesel consumption volume.

Storage
It is recommended that DEF be stored in a cool, dry, and well-ventilated area that is out of direct sunlight.

Adapted from: https://en.wikipedia.org/wiki/Diesel_exhaust_fluid
https://en.wikipedia.org/wiki/Selective_catalytic_reduction

(a) Suggest why the running of diesel engines with a lean burn air-to-fuel ratio leads to the production of more oxides of nitrogen.

…… [1]

(b) Suggest why, unlike diesel engines, petrol engines do not require the use of DEF.

……

…… [1]

(c) Which type of SCR design, honeycomb or plate, is more suitable to be fitted in cars?

Give a reason for your answer.

……
…… [1]

(d) State the overall equation for the reduction of nitrogen dioxide (NO_2) by urea.

…… [1]

(e) (i) What is the maximum volume of DEF vapour that needs to be added to 100 dm^3 of diesel vapour?

…… [1]

(i) What is the maximum volume of nitrogen gas that can be formed from the combustion of 100 dm^3 of diesel vapour if the DEF injected only contains urea?

…… [1]

(f) State why active catalytic components are usually oxides of metals such as vanadium, molybdenum and tungsten instead of Group I metals.

……

…… [1]

(g) Suggest why DEF should be stored in a cool area that is out of direct sunlight.

……

…… [1]

(h) Explain why the use of DEF is not completely environmentally friendly.

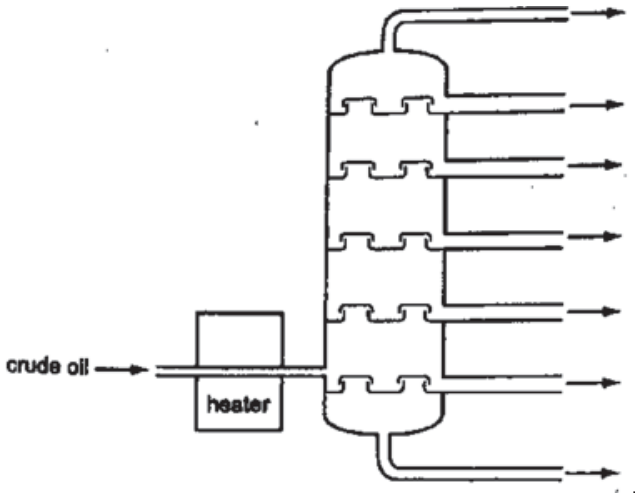
……

……

…… [2]

[Total: 10]

5 The diagram below shows how petroleum can be refined.



(a) Briefly describe how fractions can be separated through the fractional distillation of crude oil.

……...

……...

……...

……...

……...

……..[3]

(b) The flow chart below shows how a sweet smelling compound **Y** can be formed from petroleum (crude oil).

(i) Explain why Stage **A** is an important process in the energy industry.

……...

……...

……..[1]

(ii) A long chain alkane, $C_{12}H_{26}$, undergoes Stage **A** to form ethene, butane and an unsaturated compound **Z**.

Draw the structure of compound Z in the space given below.

[1]

[Total: 5 marks]

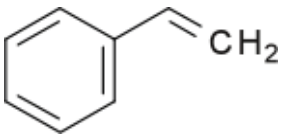
6 Styrene, a liquid hydrocarbon that is important chiefly for its marked tendency to undergo polymerisation.

Styrene is employed in the manufacture of polystyrene, an important plastic, as well as a number of specialty plastics and synthetic rubbers.

Pure styrene is a clear, colourless, flammable liquid that boils at 145 °C and freezes at -30.6 °C.

Unless treated with inhibitor chemicals, it has a tendency to polymerise spontaneously during storage. It is slightly toxic to the nervous system if ingested or inhaled, and contact with the skin and eyes can cause irritation. Although it is suspected of being carcinogenic, studies have not proved it to be so.

The chemical formula for styrene is C8H8, but its structural formula, C6H5CH=CH2, more clearly reveals the sources of its commercially useful properties.



Structural formula of styrene

Styrene is a member of a group of chemical compounds broadly categorised as vinyls—organic compounds whose molecules contain a double bond between two carbon atoms.

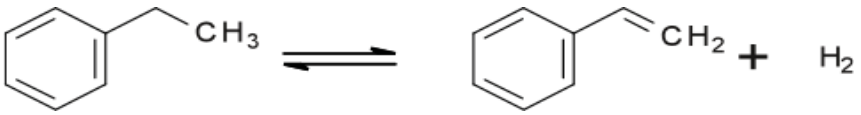
Under the action of chemical catalysts or initiators, this link contributes to the formation of polystyrene, in which thousands of styrene units are linked along a carbon backbone. Hanging from this backbone are phenyl groups (C6H5)—large ring-shaped units that interfere with the spontaneous motion of the chainlike polymer and lend polystyrene its well-known rigidity.

The phenyl group is one of the aromatic rings. Styrene, which gives off a penetrating sweetish odour, is therefore one of the aromatic hydrocarbons.

Industrial production from ethylbenzene

The modern method for production of styrene by *dehydrogenation* of ethylbenzene was first achieved in the 1930s. The production of styrene increased dramatically during the 1940s, when it was popularised as a feedstock for synthetic rubber.

Because it is produced on such a large scale, ethylbenzene is in turn prepared on a prodigious scale (by alkylation of benzene with ethylene). Ethylbenzene is mixed in the gas phase with 10–15 times its volume in high-temperature steam, and passed over a solid catalyst bed. Most ethylbenzene dehydrogenation catalysts are based on iron(III) oxide, promoted by several percent potassium oxide or potassium carbonate.



Dehydrogenation of ethylbenzene

Steam serves several roles in this reaction. It is the source of heat for powering the *endothermic* reaction, and it removes coke that tends to form on the iron(III) oxide catalyst through the water gas shift reaction. The potassium promoter enhances this decoking reaction. The steam also dilutes the reactant and products, shifting the position of chemical equilibrium towards products.

A typical styrene plant consists of two or three reactors in series, which operate under vacuum to enhance the conversion and selectivity. Typical per-pass conversions are 65% for two reactors and 70-75% for three reactors. Selectivity to styrene is 93-97%. The main byproducts are benzene and toluene. Because styrene and ethylbenzene have similar boiling points (145 °C and 136 °C, respectively), their separation requires tall distillation towers and high return/reflux ratios. At its distillation temperatures, styrene tends to polymerise. To minimize this problem, early styrene plants added elemental sulfur to inhibit the polymerisation.

During the 1970s, new free radical inhibitors consisting of nitrated phenol-based retarders were developed. More recently, a number of additives have been developed that exhibit superior inhibition against polymerization. However, the nitrated phenols are still widely used because of their relatively low cost. These reagents are added prior to the distillation.

Laboratory synthesis

A laboratory synthesis of styrene entails the decarboxylation of *cinnamic acid*.

$C_6H_5CH{=}CHCO_2H \rightarrow C_6H_5CH{=}CH_2 + CO_2$

Incineration

If polystyrene is properly incinerated at high temperatures (up to 1000 °C) and with plenty of air (14 m^3/kg), the chemicals generated are water, carbon dioxide, and possibly small amounts of residual halogen-compounds from flame-retardants. If only incomplete incineration is done, there will also be leftover carbon soot and a complex mixture of volatile compounds. According to the American Chemistry Council, when polystyrene is incinerated in modern facilities, the final volume is 1% of the starting volume; most of the polystyrene is converted into carbon dioxide, water vapor, and heat. Because of the amount of heat released, it is sometimes used as a power source for steam or electricity generation.

Adapted from: https://www.britannica.com/science/styrene
https://en.wikipedia.org/wiki/Styrene

https://en.wikipedia.org/wiki/Polystyrene

(a) Draw the 'dot and cross' diagram of styrene, showing only the outermost electrons.

[2]

(b) Explain why styrene has a low melting point of -30.6 °C.

……

…… [2]

(c) Explain the type of reaction that occurs in the dehydrogenation process.

…… [1]

(d) Explain why tall distillation towers are necessary for the separation of styrene and ethylbenzene.

……

…… [1]

(e) Draw the repeating unit of polystyrene.

[1]

(f) Write down a balanced chemical equation for the incineration of polystyrene (2 repeat unit) in modern facilitates.

…… [1]

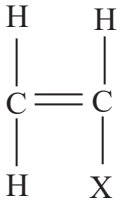
(g) Describe, with a balanced equation, what would be observed when sodium carbonate is put into cinnamic acid.

……

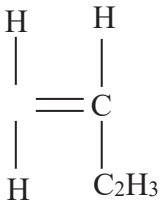
…….. [2]

[Total: 10]

7 **(a)** Styrene-butadiene rubber is a synthetic rubber. It is made by polymerizing a mixture of the monomers butadiene and styrene.



styrene

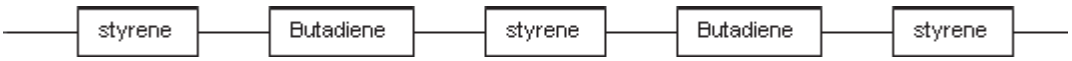


butadiene

(i) What type of polymerisation will take place when the monomers polymerize?

…… [1]

One possible structure for the polymer is shown below.



(ii) Give the full structural formula for the repeating unit in this polymer structure.

[1]

(iii) When the mixture of styrene and butadiene polymerizes, the polymer is unlikely to contain only this regular, repeating pattern. Explain why.

……

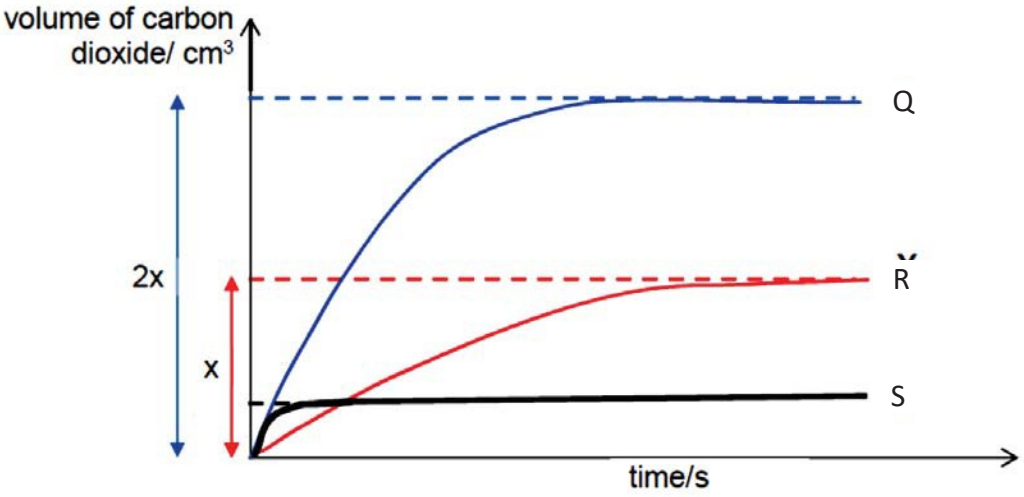
…… [1]

(iv) Butadiene is obtained from the cracking of butane. 2.90 kg of butane entered the cracking tower. The percentage yield of butadiene is 75%. Calculate the mass of butadiene obtained from the cracking process.

[1]

(b) Three different experiments were carried out using metal carbonates and acids. The table below shows the reactants used in each of the experiment. The graph shows the results of the experiments.

experiment	reactants
Q	150 cm^3 of 2.0 mol/dm^3 H_2SO_4 (aq) + 26.5g Na_2CO_3 (s)
R	v cm^3 of 1.0 mol/dm^3 H_2SO_4 (aq) + excess Na_2CO_3 (s)
S	150 cm^3 of z mol/dm^3 H_2SO_4 (aq) + excess $CaCO_3$ (s)



(i) Identify the limiting reagent in experiment Q.

[2]

(ii) Calculate the volume of carbon dioxide gas produced in experiment R and hence calculate the volume, v cm^3, of sulfuric acid used.

Volume of carbon dioxide = ……..

v =……..…….[2]

(iii) From the graph, deduce the concentration of sulfuric acid used in experiment S.

Concentration of sulfuric acid =

…….[1]

(iv) The mass of the salt formed in experiment S is much lower than expected. Write a balanced chemical equation, including state symbols, to suggest another reaction that can prepare a greater mass of this salt.

…….[1]

[Total: 10]

8 **(a)** A student reacted together an alcohol and a carboxylic acid under appropriate conditions to produce an ester.

A sweet smelling organic liquid, **Q**, with the empirical formula C_2H_4O was produced. The M_r of **Q** was found by experiments to be 87.5.

(i) What is the molecular formula of **Q**? Show the necessary calculation. [1]

(ii) In the boxes below, draw the structural formula of **two** isomers with this formula that are **straight chain** esters. [2]

A sample of **Q** was heated with aqueous sulfuric acid. The product obtained was a mixture of the original alcohol and carboxylic acid. This mixture was heated under reflux with acidified potassium manganate(VII) to give a **single** product, **R**.

The product, **R**, was collected and subjected to the following tests:

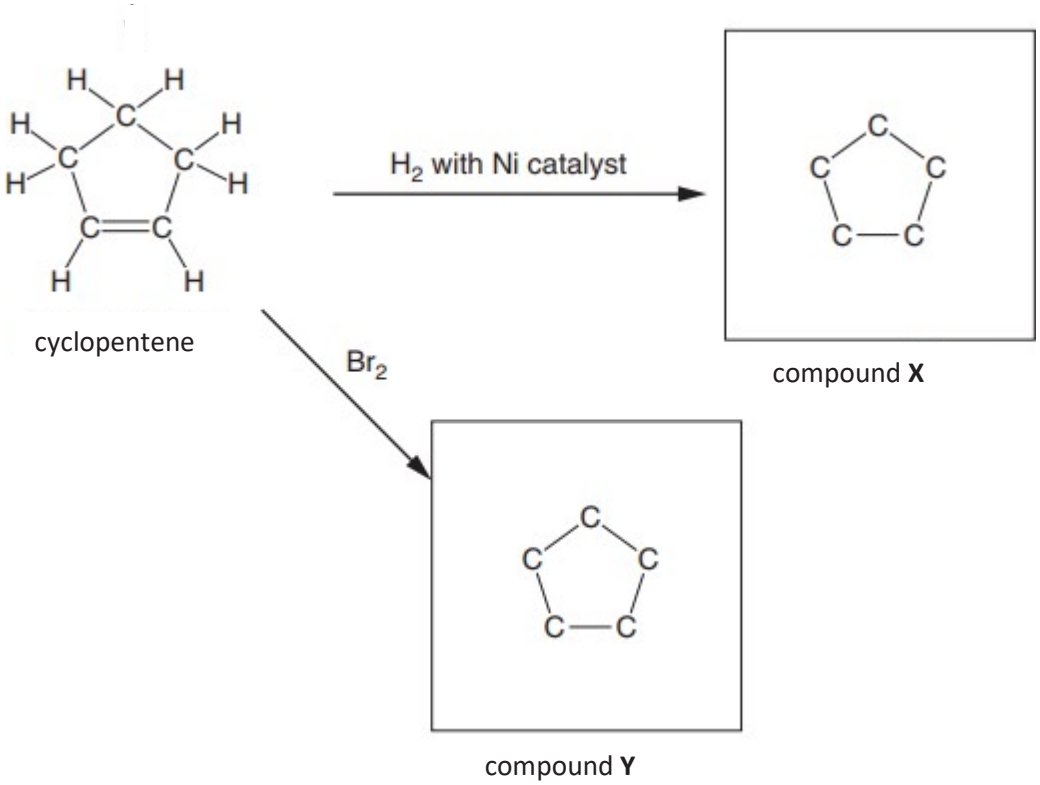
- A sample of **R** gave no reaction with aqueous bromine.
- A second sample of **R** gave an effervescence with sodium carbonate.
- A third sample of **R** is completely miscible with water.

(iii) What is the identity of single organic compound **R**?

…… [1]

(b) Cyclopentene is a cyclic alkene with the formula C_5H_8. It is a colourless liquid with a petrol-like odour. It is used as a monomers for synthesis of plastics.
The figure below shows some reactions involving cyclopentene

(i) Complete the partial structures of compounds **X** and **Y** which are the products of the reactions. [2]



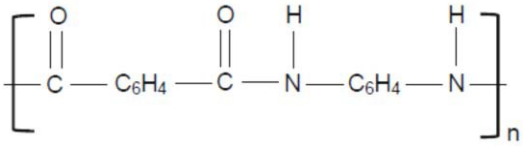
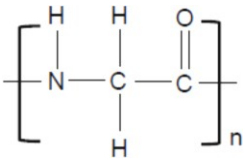
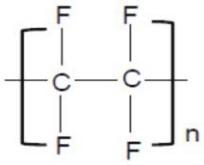
(ii) Write a balanced chemical equation to show the reaction between cyclopentene and aqueous bromine.

..... [1]

(iii) Cyclopentene can be polymerised to give poly(cyclopentene). Draw a section of poly(cyclopentene) to show two repeat units. [1]

[Total: 8]

9 The table below shows some information regarding three materials. They are Kevlar, polyglycine and Teflon.

name of material	structure of polymer
Kevlar	
polyglycine	
Teflon	

(a) Identify the reaction that formed

(i) Kevlar, ... [1]

(ii) polyglycine, ... [1]

(iii) Teflon. ..... [1]

(b) During polymerisation to form Kevlar and polyglycine, hydrogen chloride and water are released respectively.

Draw the structure of the monomer(s) that formed

(i) Kevlar,

[2]

(ii) polyglycine.

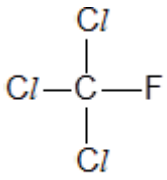
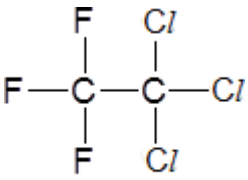
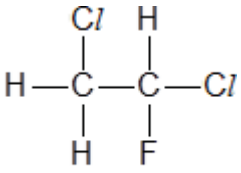
[1]

(c) Suggest the structural formulae of the products formed from a reaction between glycine and ethanol.

[2]

[Total: 8]

10 Chlorofluorocarbons (CFCs) are inert on the Earth's surface. However in the stratosphere, they are very reactive. CFCs are part of a group of compounds which can be classfied as ozone depleting compounds. Other than CFCs, there are also hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs) and perfluorocarbons (PFCs). Some common examples of CFC and HCFC molecules are shown below with their names.

 CFC-11	 CFC-113a	 HCFC-141

A naming system for these substances was devised several decades ago. The prefixes to the name tell us the elements present in the compound as shown in the table below.

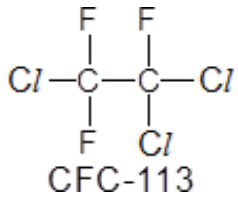
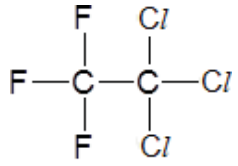
prefix	elements present
PFC	carbon, fluorine
CFC	carbon, fluorine, chlorine
HFC	hydrogen, carbon, fluorine
HCFC	hydrogen, carbon, fluorine, chlorine

The numbers suffixed to the names of the compounds give us the number of each type of atom present in one molecule of the compound. The key to decoding the number is simply to add 90 to the number suffixed to the name.

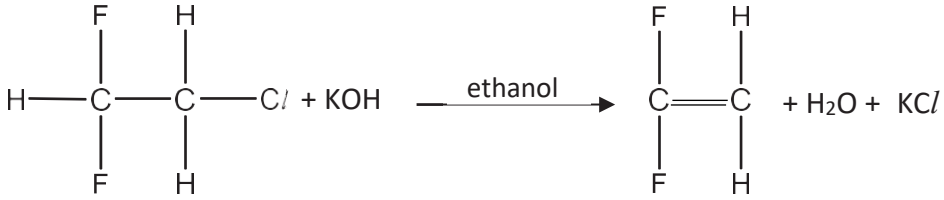
.

For example, to decode the number of atoms in CFC-113a, we add 113 to 90 to obtain 203. The first number, 2, tells us the number of carbon atoms, the second number, 0, tells us the number of hydrogen atoms, and the third number, 3, tells us the number of fluorine atoms. Chlorine atoms make up the remaining bonds since all these compounds are saturated.

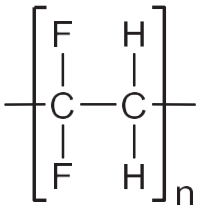
The letter 'a' in CFC-113a tells us about the structural formula of the compound. The arrangement of the type of atoms in the compound that most evenly distributes atomic masses has no letter. The second most even distribution is given the letter 'a', the third most even distribution is given the letter 'b', so on and so forth.

molecule	atomic mass on left carbon	atomic mass on right carbon
 CFC-113	73.5	90
 CFC-113a	57	106.5

Although most of these substances are harmful to the ozone layer, they can also be used to make polymers by first converting them to alkenes. For example, HCFCs react with potassium hydroxide which is dissolved in ethanol (solvent) to give an alkene, potassium chloride and water. An example of the reaction is shown below.



The alkene produced from the above reaction can be used to make useful polymers such as the one shown below.



(a) Draw the structure of a PFC molecule with two carbon atoms. [1]

(b) Copy the table below and draw the other two isomers of HCFC-141 in the correct respective boxes. [2]

HCFC-141a	HCFC-141b

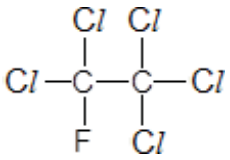
(c) A student comments that HFCs are safer alternatives to CFCs as HFCs do not harm the environment like CFCs do.

Explain why the student is correct.

..... [1]

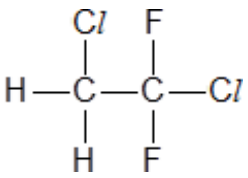
(d) Use the naming system discussed in the passage, write down the names of the following molecules.

(i)



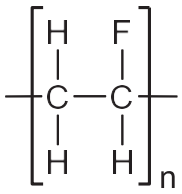
..... [1]

(ii)



..... [2]

(e) **(i)** A scientist wants to produce the polymer, polyvinyl fluoride, using HCFCs.



polyvinyl fluoride

Using a suitable HCFC, write down **two** equations showing the reactions he has to carry out to produce polyvinyl fluoride. Show the structures of all the organic compounds in your equations. [3]

(ii) Samples of the polyvinyl fluoride polymer produced were analysed and found to have a maximum relative molecular mass of 12000.

What is the maximum number of repeating units for this polymer?

..... [2]

[Total: 12]

11 The general structure of an amino acid is given below:

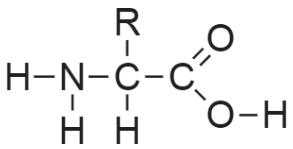


Figure 8.1

where R could just be a simple hydrogen atom or a functional group such as amino or carboxyl group.

The structure below gives a segment of a polypeptide chain with 2 amino acid residues, one with an amino group and another one with a carboxyl group for their R group, when placed in a solution with a pH of 7.

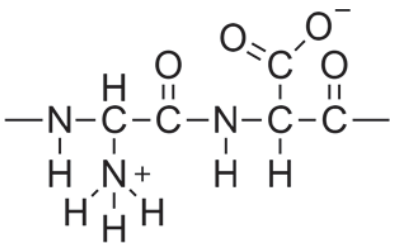


Figure 8.2

(a) Use the structures in Figures 8.1 and 8.2 to explain why

(i) an amino acid is said to be *amphoteric*; and

.....

.....

.....[2]

(ii) a polypeptide chain is said to be a *condensation polymer*.

.....

.....

.....[2]

(b) A protein molecule is formed by one or more polypeptide chains interacting and folding into a three-dimensional structure.

At extreme pH values, this three-dimensional structure of the protein would be altered, causing the molecule to denature and lose its function.

With reference to Figure 8.2, suggest why the shape of the molecule would be altered at different pH values.

.....

.....

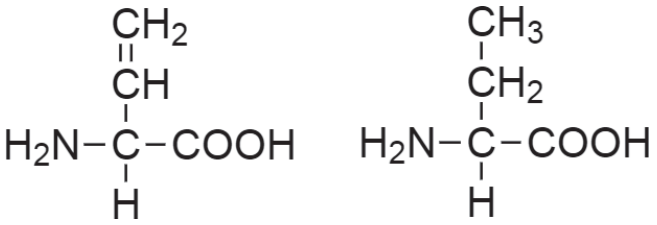
.....

.....[3]

(c) Name a synthetic polymer with similar linkage to polypeptides.

.....[1]

(d) You are given two bottles of solution, each containing a different amino acid as shown in Figure 8.3.



amino acid **J** amino acid **K**

Figure 8.3

Describe a simple chemical test to distinguish between these two amino acids, **J** and **K**.

.....

.....

.....[2]

[Total: 10]

12 Fats and oils are triglycerides formed from the condensation reaction of propane-1,2,3-triol with long chain carboxylic acids (fatty acids). Each triglyceride is formed from three fatty acids.

Fig. 8.1 shows the structural formula of a triglyceride likely to be found in peanut oil.

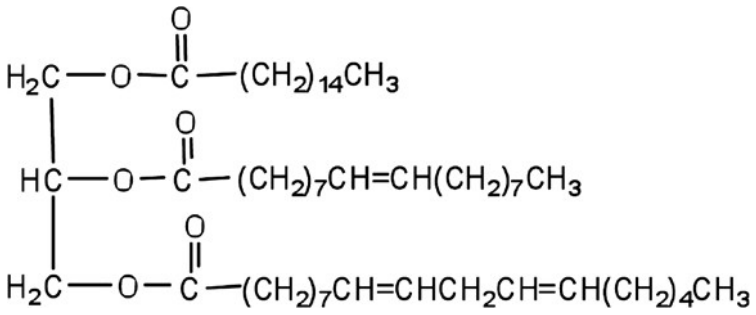


Fig. 8.1

A triglyceride is considered a fat if it is a solid at 25°C, whereas it is considered an oil if it is a liquid at 25°C. These differences in melting points reflect the differences in the degree of unsaturation and molar mass of the constituent fatty acids.

One method for checking the unsaturation level in fatty acids is to determine the iodine number. *Iodine number* is the number of grams of iodine consumed by 100 g of fat or oil. A higher iodine value indicates a higher degree of unsaturation.

Table 8.2 shows average figures for the percentage fatty acid composition of some common fats and oils.

Table 8.2

source of fat or oil	% saturated fatty acids (total)	% monounsaturated fatty acid, oleic acid ($C_{17}H_{33}COOH$)	% polyunsaturated fatty acids	
			linoleic acid ($C_{17}H_{31}COOH$)	linolenic acid ($C_{17}H_{29}COOH$)
beef fat	59	38	3	—
coconut oil	90	8	2	—
corn oil	25	26	47	2
cotton seed oil	22	35	43	—
olive oil	15	78	7	—
soybean oil	14	28	50	8

The *polyunsaturated/saturated (P/S) index* of a fat or oil is the ratio of polyunsaturated fat to saturated fat. It is sometimes used to compare the relative health benefits of different fats and oils in the diet.

The above passage is modified from https://2012books.lardbucket.org/books/introduction-to-chemistry- general-organic-and-biological/s20-lipids.html.

(a) **(i)** State the chemical linkage which is observed in Fig. 8.1.

…… [1]

(ii) Identify the by-product formed for the reaction of propane-1,2,3-triol with three long chain carboxylic acids (fatty acids).

…… [1]

(iii) Draw the structural formulae of **two** reactants that are used to produce the triglyceride, as seen in Fig. 8.1.

- reactant 1: propane-1,2,3-triol

- reactant 2: one of the carboxylic acids

[2]

(b) Using the information in Table 8.2, deduce and explain which fat or oil has the lowest iodine number.

……

…… [2]

(c) Although cotton seed oil and corn oil have similar iodine numbers, the melting point of cotton seed oil is higher than that of corn oil.

Suggest an explanation, in terms of the structure and bonding, in these two oils.

……

……

……

……

…… [2]

(d) Linoleic acid is a polyunsaturated fatty acid with molecular formula of $C_{17}H_{31}COOH$.

How many double bonds between carbon atoms are present in one molecule of linoleic acid? Explain your reasoning.

……

……

……

……

…… [2]

(e) A P/S value of greater than 1 is considered beneficial for health.

Calculate the P/S index of coconut oil and soybean oil, giving your answers to 3 significant figures.

Hence, determine which oil, coconut oil or soybean oil, is more beneficial for health.

…… [3]

[Total: 13]

13 Dieticians recommend that saturated fats in our diet be replaced by polyunsaturated vegetable oils. Vegetable oils can often be converted by reacting with hydrogen through a process called hydrogenation.

(a) (i) Define the term 'polyunsaturated'

_____[1]

(ii) What type of reaction is hydrogenation?

_____[1]

(iii) Name a catalyst needed for the reaction in **(b) (i).**

_____[1]

(iv) 10.0 g of an oil (M_r = 800) is completely reacted with 1.80 dm^3 of hydrogen measured at r.t.p.

Calculate the number of moles of hydrogen that will react with one mole of the oil. Hence deduce the number of C=C bonds present in each molecule of the oil.

(b) In the table below, state the IUPAC name of the ester that is formed using each corresponding pair of alcohol and carboxylic acid.

	alcohol	carboxylic acid	ester
(i)	propan-1- ol	ethanoic acid	
(ii)	butan-1-ol	propanoic acid	

[2]

14 The following is a list of formulae of organic compounds.

C_2H_5OH C_3H_8 C_4H_8 C_5H_{10} $C_5H_{11}COOH$

(a) (i) State the compounds that belong to the same homologous series. [2]

_____

(ii) Name the homologous series. [1]

_____

(b) List all the non-hydrocarbons. [2]

_____

(c) Draw the full structural formula for C_2H_5OH. [1]

(d) Write the condensed structural formula for C_3H_8. [1]

(e) $C_5H_{11}COOH$ can exist as four isomeric compounds.

(i) Complete the IUPAC name of one of the isomers. [1]

3-methyl_____

(ii) Draw the full structural formula of the isomer. [1]

15 When propane reacts with chlorine, two different monosubstituted propanes are produced.

(a) State the condition(s) needed for the reaction. [1]

_____

(b) Draw the structural formula of each of the two isomeric products and give its IUPAC name. [4]

Structural formula	IUPAC name

16 The following is a list of formulae of organic compounds.

CH_3COOH C_5H_{12} C_2H_5OH C_3H_6 C_7H_{14}

Which of the above formulae fit the following descriptions?

(a) A compound which dissolves to form an acidic solution [1]

_____

(b) A compound which is not a hydrocarbon. [1]

_____

(c) Two compounds which are from the same homologous series. [1]

_____

(d) Two compounds which react to form an ester. [1]

_____

(e) A compound which undergoes an addition reaction with steam. [1]

_____

17 Olive oil contains oleic acid which is unsaturated.

(a) By naming the reagent and giving the observation, describe a simple test to confirm that olive oil contains an acid. [2]

_____

_____

_____

(b) Explain what is meant by the term "unsaturated" [1]

_____

_____

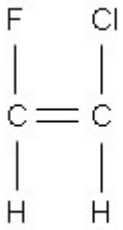
By naming the reagent and giving the observation, describe a simple test to confirm that (c) oleic acid is unsaturated.

_____

_____

_____

18 The structure of chlorofluoroethene is shown below:



(a) Name and draw the structure of the macromolecule formed when chlorofluoroethene polymerises [2]

(b) When 20.5 tonnes of chlorofluoroethene is polymerized, 18.5 tonnes of the polymer were obtained. Calculate the percentage yield. [1]

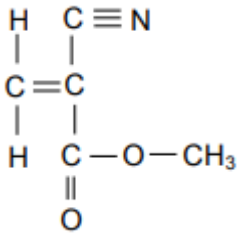
(c) Name and give the use for a commercially available polymer containing a halogen. [2]

_____

_____

_____

19 **(a)** 'Superglue' contains the following monomer:



The monomer is rapidly polymerised by traces of bases on the surfaces of objects to be stuck together, causing the glue to solidify.

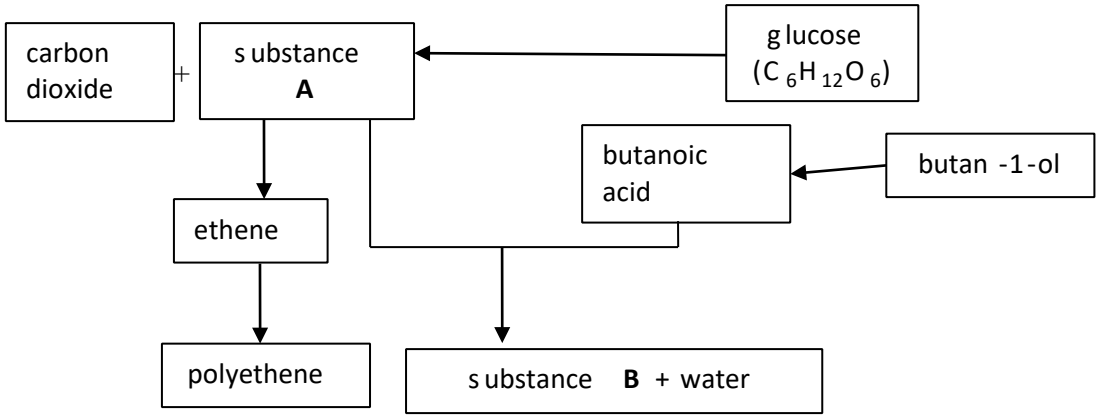
(i) What type of polymerisation takes place when the glue is in use? [1]

_____

(ii) Draw a repeat unit of the polymerised form of the glue. [1]

(iii) Calculate the percentage by mass of carbon in the polymer. [1]

20 Glucose undergoes fermentation as shown in the following diagram:



(a) Draw the full structural formula of substance **A** and state its IUPAC name. [2]

IUPAC name: _____

(b) Give the conditions and reagents required for the formation of substance **A** [2] from glucose.

_____

_____

(c) **(i)** Substance **A** and butanoic acid reacts to form substance **B** and water. Give the IUPAC name and full structural formula substance **B**. [2]

IUPAC name: _____

(ii) Give two common consumer products which could contain substance **B.** [2]

_____

(d) Give the conditions and reagents needed to convert butan-1-ol to butanoic acid. [1]

_____

21 Ethanoic acid is produced on an industrial scale by the oxidation of ethanol.

(a) Ethanol is a member of the homologous series of alcohols.

(i) State the IUPAC name and draw the structure of the next member of alcohol in the series

[2]

IUPAC name : _____

(ii) Explain why the boiling point of this alcohol is higher than the boiling point of ethanol? [1]

_____

_____

_____

(d) (i) Name the product formed when propanoic acid reacts with ethanol. [1]

_____

(ii) Write the equation for this reaction. [1]

_____

22 The table below shows some information about a homologous series of carbon compounds called ethers.

name	number of carbon atoms	formula	boiling point / °C
methoxymethane	2	CH_3OCH_3	−24.8
methoxyethane	3	$CH_3OC_2H_5$	7.0
methoxypropane	4	CH3OC3H7	
	5		70.3

(a) Deduce the name and formula of the ether that contains 5 carbon atoms. [2]

_____

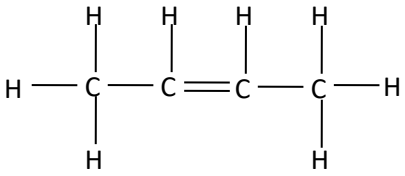
(b) Suggest a value for the boiling point of methoxypropane. [1]

_____

(c) One of the first anesthetics used to stop pain during surgical operations was ethoxyethane, $C_2H_5OC_2H_5$. It is explosively flammable and so was very hazardous for doctors to use.
Write an equation for the complete combustion for ethoxyethane. [2]

_____

23 But-2-ene has the structural formula shown below.



but-2-ene

(d) Draw two isomers of but-2-ene. [2]

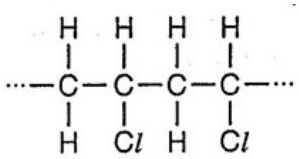
(e) State the type of polymerization that but-2-ene undergoes?
Explain your reasoning. [2]

_____

_____

(c) Give the full structural formula of the polymer formed, showing at least three repeat units. [1]

24 The partial structure of a common plastic, polymer **X**, is represented by 2 repeating units of the polymer as shown. Polymer **X** is formed when monomer **Y** undergoes polymerisation.



(a) Draw the structure of the monomer **Y**, from which it is made. [1]

(b) Name the type of polymerisation that convert monomer **Y** to polymer **X**. [1]

_____

(c) Name one disadvantage of using common plastics such as polymer **X.** [1]

_____

(d) Monomer **Y** reacts with steam, in the presence of a catalyst, to form 1-chloroethanol. Name the catalyst used. [1]

_____

(e) Another organic compound with the molecular formula, C_4H_8, undergoes reaction with hydrogen gas to form an alkane. Give the conditions and reagents needed for this reaction. [2]

_____

ANSWERS FOR ORGANIC CHEMISTRY MCQ

Paper 1

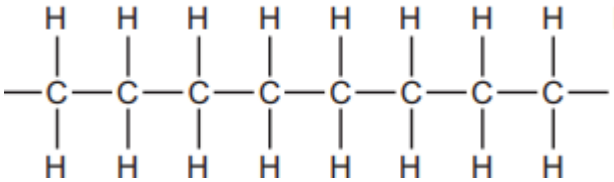
1 The table shows the energy released by complete combustion of some compounds used as fuels.

compound	Mr	I\H (kJ/mo)
methane	16	-880
ethanol	46	-1380
propane	44	-2200
heptane	100	-4800

Which fuel produces the least energy when 1 g of the compound is completely burned?

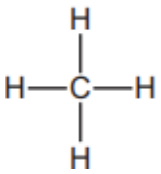
A methane
B ethanol
C propane
D heptane

2 The diagram shows part of the molecule of a polymer. Ans: C

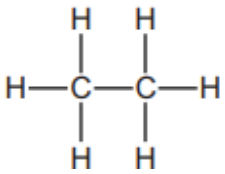


Which diagram shows the monomer from which this polymer could be manufactured?

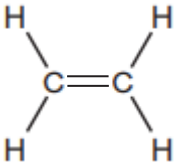
A



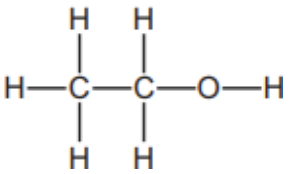
B



C



D



3 Which compound will react with steam, in the presence of catalyst, to produce the alcohol $CH_3CH_2CH_2OH$?

A CH_3CHCH_2
B $CH_3CHCHCH_3$
C $CH_3CH_2CH_2CH_3$
D CH_3CH_2COOH

4 Which type of reaction does this equation show?

$$C_3H_8 + F_2 \rightarrow C_3H_7F + HF$$

A Hydration
B Neutralisation
C Addition
D Substitution

5 An unsaturated hydrocarbon with six carbon atoms contains only three C=C double bonds. This hydrocarbon is reacted with excess bromine at a room temperature.

What is the formula of the resulting hydrocarbon?

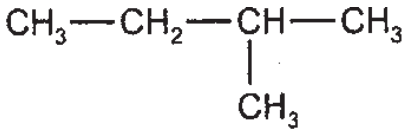
A $C_6H_8Br_3$
B $C_6H_{10}Br_3$
C $C_6H_8Br_6$
D C_6H_{14}

6 A hydrocarbon is found to contain about 80% of carbon by mass. What is the hydrocarbon?

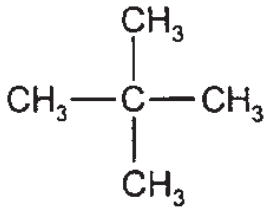
A Methane
B Ethene
C Propane
D Hexene

7 Which structure is not an isomer of the structure shown? Ans :C

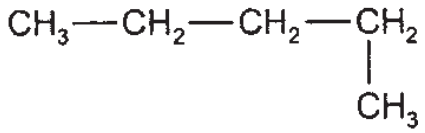
A



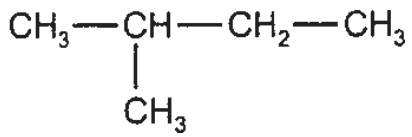
B



C



D

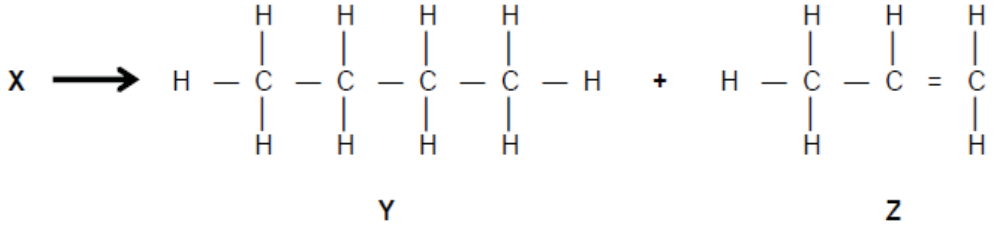


8 Some unsaturated compounds contain more than one carbon-carbon double bond. An example is the compound with the formula $C_{21}H_{26}$.

How many carbon-carbon double bonds are present in one molecule of this compound?

A 3
B 5
C 8
D 9

9 A chemist carried out a cracking reaction on a hydrocarbon, **X** and obtained two products, **Y** and **Z**.



The chemist then wrote the following statements in his notebook.

(1) A molecule of **X** has 7 carbon atoms.
(2) **Y** is unsaturated.
(3) **Z** will decolourise bromine water.

Which statement(s) is/are correct?

A (3) only
B (1) and (2)
C (1) and (3)
D (1), (2) and (3)

10 The table shows the boiling points of four fractions when crude oil is distilled.

fraction	W	X	Y	Z
boiling point /°C	35 - 75	80 - 145	150 - 250	greater than 250

Which statement regarding the fractions is true?

A Fraction W is more flammable than fraction Y.
B Fraction W is more viscous than fraction Z
C The density of fraction X is greater than that of fraction Z.
D The molecules in X have a longer chain length than those in fraction Z.

11 1 mole of a compound X reacts completely with 2 moles of hydrogen gas in the presence of a catalyst to form 1 mole of alkane.

Which compound could X be?

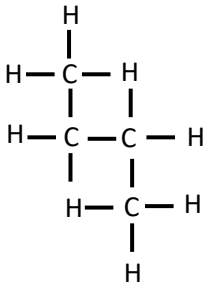
A $CH_2=CH-CH=CH-CH=CH_2$

B $CH_2=CH-CH_2-CH_2-CH=CH_2$

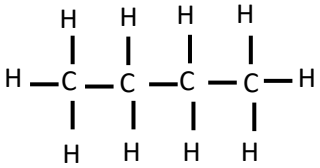
C $CH_2=CH-CH_2-CH_2-CH_2-CH_3$

D $CH_2=CH-CH_2-CH_2-COH=CH_2$

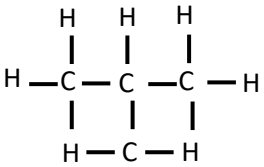
12 Which of these molecules have the same boiling points?



P



Q



R

A P and Q

B P and R

C Q and R

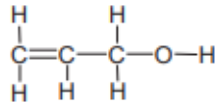
D P, Q and R

13 An organic compound S has the following reactions:

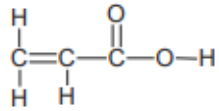
- neutralises sodium hydroxide
- decolourises aqueous bromine

Which structure represents S?

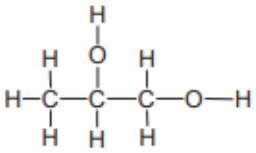
A



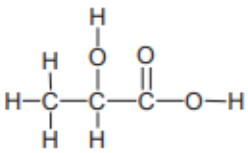
B



C



D



14 Which statement describes the property of the first fraction obtained from the fractional distillation of crude oil?

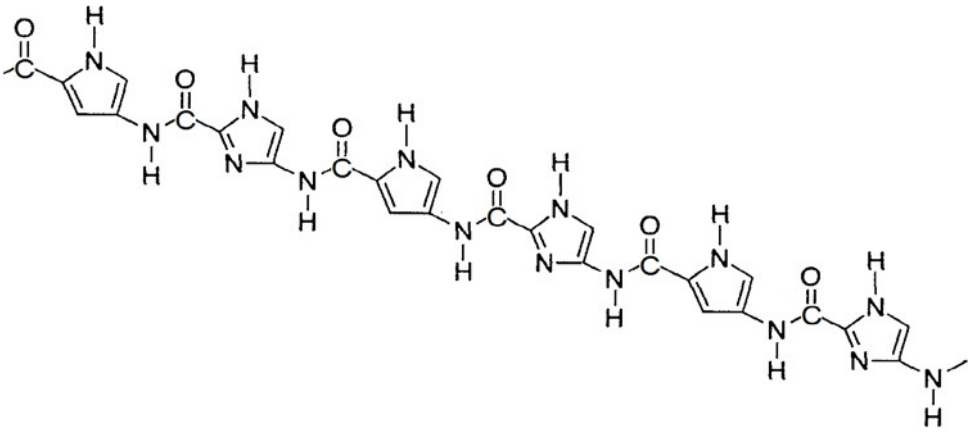
A It gives the most sooty flame when burnt.

B It has the highest boiling point.

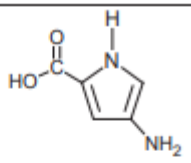
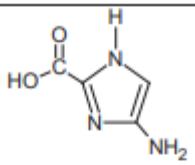
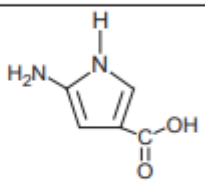
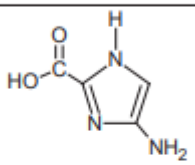
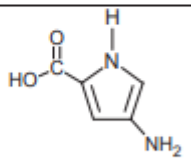
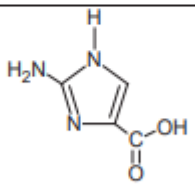
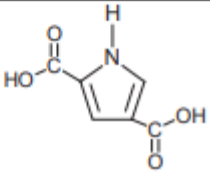
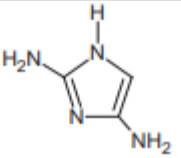
C It is the most miscible with organic solvent.

D It is the most viscous.

15 The structure below shows part of a polymer.



Which option shows the correct monomers? Ans : A

	monomer 1	monomer 2
A		
B		
C		
D		

16 The compound, C_8H_{18} undergoes the following process.

$$C_8H_{18} \xrightarrow{\text{Process X}} \text{Ethene + Compound Y}$$

Which row in the table correctly identifies Process X and Compound Y?

	Process X	Compound Y
A	cracking	hexane
B	cracking	hexene
C	distillation	hexane
D	distillation	hexene

17 How many moles of hydrogen chloride are formed when one mole of methane is added to a large excess of chlorine in the dark?

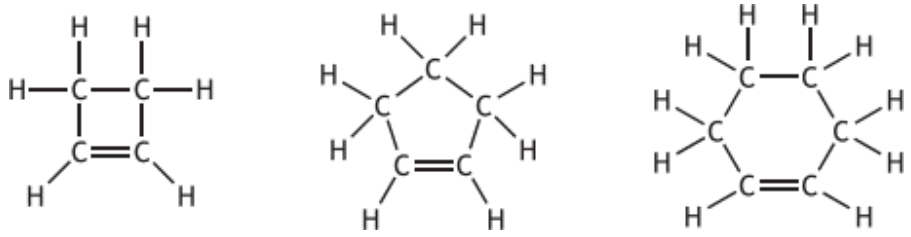
A 0

B 1

C 2

D 4

18 Three members of the cycloalkene homologous series are shown:



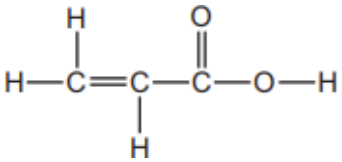
Which of the following is the general formula for this homolog1ous series?

A C_nH_{2n-4}
B C_nH_{2n-2}
C C_nH_{2n}
D C_nH2_{n+2}

19 Oil contains carbon-carbon double bonds which can undergo addition reactions with iodine. The iodine number of an oil is the mass of iodine in grams that will react with 100 g of oil.
Which row in the table shows the oil that is likely to have the lowest melting point?

	oil	iodine number
A	corn	123
B	linseed	179
C	olive	81
D	soya	130

20 A compound has the following structure.



Which reaction(s) will occur with this compound?

1 Bromine water will decolourise.
2 It will react with an alcohol to form an ester.
3 It will react with sodium metal.

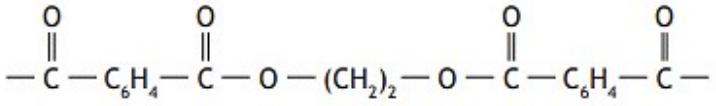
A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

21 Polyvinyl chloride (PVC) is a man-made polymer used mainly in the manufacture of pipes. PVC pipes are strong, lightweight and does not rot.
Which statements correctly describe the polymer, polyvinyl chloride, PVC?

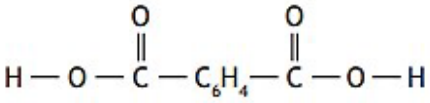
4 Combustion of PVC waste produces a highly acidic gas.
5 PVC molecules are saturated.
6 The empirical formula of PVC is the same as the empirical formula of its monomers.

A 1 and 2 only
B 1 and 3 only
C 2 and 3 only
D 1, 2 and 3

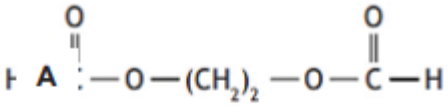
22 A section of a condensation polymer is shown below.

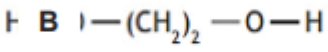


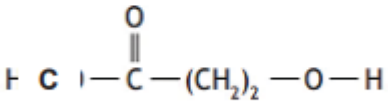
One of the monomers is

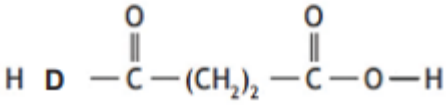


The structural formula of the other monomer is Ans B

A 

B 

C 

D 

23 Which statement(s) best explains why bitumen has a higher boiling point than paraffin?

5 Bitumen is more reactive than paraffin.
6 Bitumen is a pure substance whereas paraffin is a mixture.
7 Forces of attraction between the molecules of paraffin are weaker than that between the molecules of bitumen.
8 There are smaller molecules in bitumen compared to the molecules in paraffin.

A 1 and 2
B 1, 2 and 3
C 3 only
D 3 and 4

24 Which compound is the most viscousand the least flammable?

A C_6H_{14}
B C_8H_{18}
C $C_{10}H_{22}$
D $C_{12}H_{26}$

25 The second member of a homologous series has the formula C_7H_8.

What is the formula of the first member?

A C_6H_6
B C_6H_8
C C_6H_7
D C_7H_6

26 An ester is produced by reacting together the carboxylic acid HCO_2H and the alcohol $CH_3CH_2CH_2OH$.

What is the name and structure of this ester?

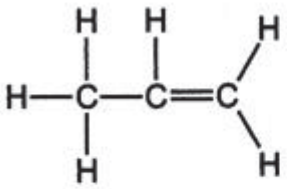
	name	structure
A	methyl propanoate	$CH_3CH_2CO_2CH_3$
B	methyl propanoate	$HCO_2CH_2CH_2CH_3$
C	propyl methanoate	$CH_3CH_2CO_2CH_3$
D	propyl methanoate	$HCO_2CH_2CH_2CH_3$

27 Compound Y

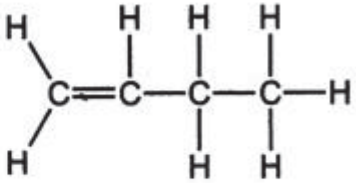
- has the empirical formula CH_2,
- has an M_r of 56,
- forms two alcohols that have different structural formulae when reacted with steam.

What is compound Y?

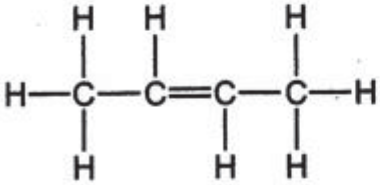
A



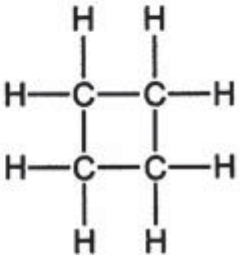
B



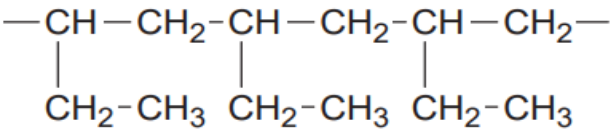
C



D



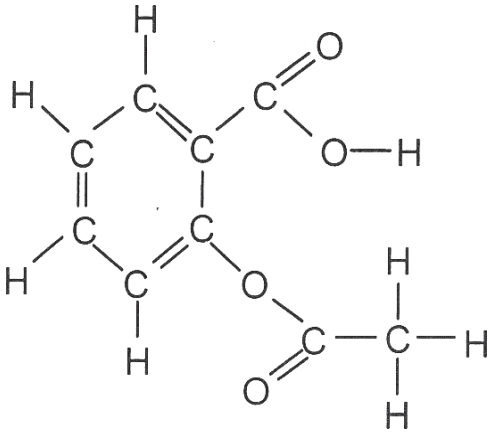
28 The structure of a polymer is shown below.



What is the molecular formula of the monomer?

A C_2H_4
B C_3H_8
C C_4H_8
D C_4H_{10}

29 Aspirin is a drug which is used as a general pain killer. The structural formula of aspirin is shown below.



Which of the following statements about aspirin is **false**?

A Its aqueous solution reacts with sodium carbonate.
B It decolourised aqueous bromine.
C It is formed from an alcohol and a carboxylic acid.
D It turns purple acidified aqueous potassium manganate (VII) colourless.

30 The diagrams show four monomers.

How many of these monomers would react with the molecule below to form a polymer?

A 1
B 2
C 3
D 4

31 The enthalpy change for the complete combustion of three different fuels, methane, ethanol and propene are as shown below.

fuel	formula	M_r	enthalpy change of combustion / kJ/mol
methane	CH_4	16	-100
ethanol	C_2H_5OH	46	-75
propene	C_3H_6	42	-170

What is the correct order of fuels, starting from the fuel that provides the most energy per gram of fuel, when the fuel undergoes complete combustion?

A methane, propene, ethanol
B methane, ethanol, propene
C propene, methane, ethanol
D ethanol, propene, methane

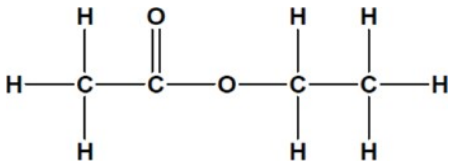
32 The table shows the boiling points of four fractions, P, Q, R and S, obtained when crude oil is distilled.

Fraction	P	Q	R	S
Boiling Range / °C	35-75	80-145	150-250	greater than 250

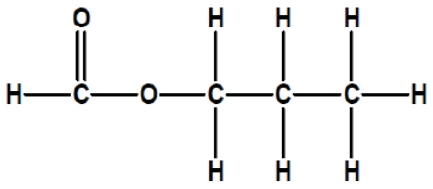
How is fraction P different from S?

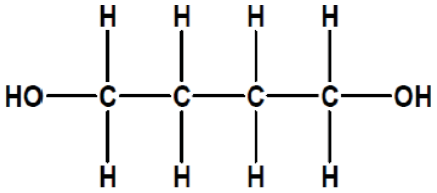
A Fraction P is more viscous than fraction S.
B Fraction P is in less demand than fraction S.
C Fraction P is more flammable than fraction S.
D Fraction P contains molecules of larger molecular masses than fraction S.

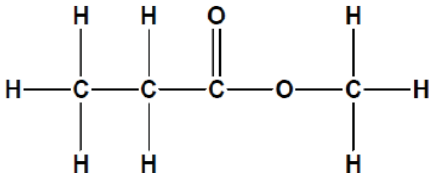
33 The diagram shows the structure of ethyl ethanoate.

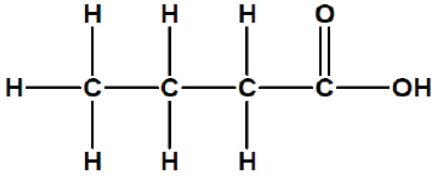


Which structure is **not** an isomer of ethyl ethanoate? Ans: B

A


B


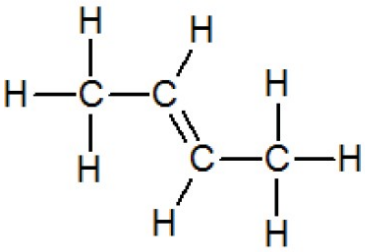
C


D


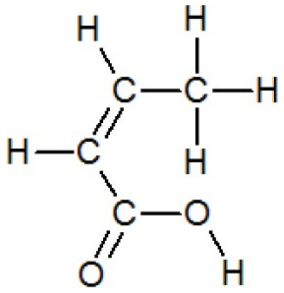
34 60 cm^3 of oxygen was mixed with 10 cm^3 of gaseous hydrocarbon in a closed vessel. After explosion and cooling, the gases occupied 50 cm^3 and after passing the gas through aqueous sodium hydroxide, 30 cm^3 of oxygen remained. Deduce the molecular formula of the hydrocarbon.

A CH_4
B C_2H_4
C C_2H_6
D C_3H_6

35 The full structural formulae of compounds X and Y are shown below.



Compound **X**



Compound **Y**

The **best** method to distinguish between X and Y visually is by using

A aqueous bromine
B potassium hydroxide solution
C potassium carbonate solution
D acidified potassium manganate(VII) solution

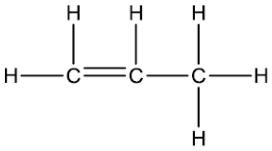
36 A food chemist wants to create the odour of pineapples for a product. An ester with this odour has the formula $C_3H_7CO_2C_4H_9$.

Which pair of substances will react to produce this ester?

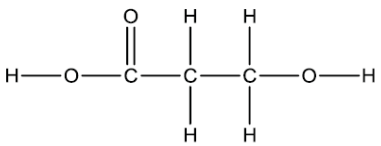
A $C_2H_5CO_2H$ and C_4H_9OH
B $C_2H_5CO_2H$ and C_3H_7OH
C $C_4H_9CO_2H$ and C_3H_7OH
D $C_3H_7CO_2H$ and C_4H_9OH

37 Which compounds would undergo polymerisation on their own?

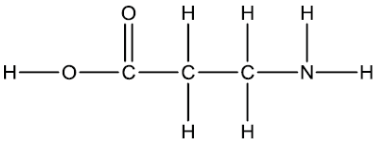
1



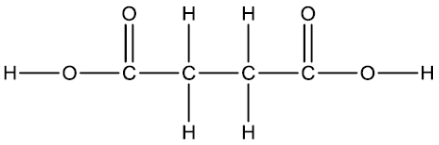
2



3

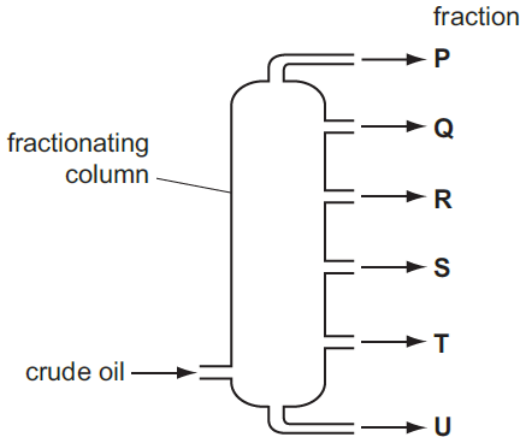


4



A 1 and 2 only
B 2 and 3 only
C 1, 2 and 3 only
D 1, 2, 3 and 4

38 The diagram shows the fractional distillation of crude oil.



Which statement is correct?

A Each fraction consists of a single compound.
B Fraction P has the highest boiling point.
C The highest temperature is at the top of the column.
D The naphtha fraction is used as feedstock for the chemical industry.

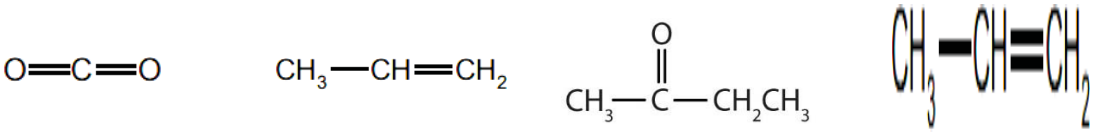
39 Which property of a liquid ester can be used to check its purity before use as a food flavouring?

A boiling point
B smell
C colour
D smell

40 Which compound is the most viscous and the least flammable?

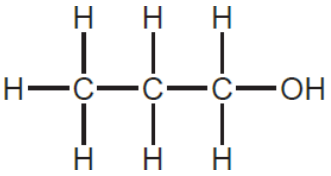
A C_6H_{14}
B C_8H_{18}
C $C_{10}H_{22}$
D $C_{12}H_{26}$

41 How many of the following structures show an unsaturated hydrocarbon molecule?



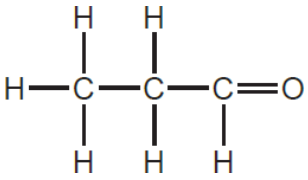
A 1
B 2
C 3
D 4

42 This is the structural of propan-1-ol.

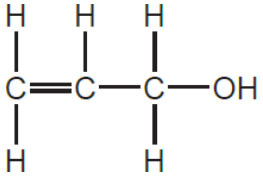


Which of the following is an isomer of propan-1-ol? Ans: B

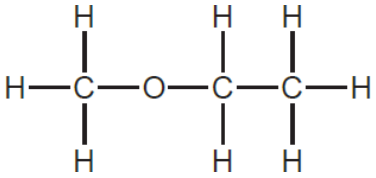
C



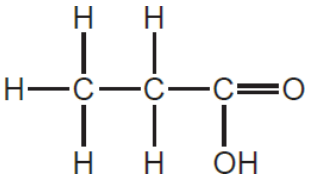
C



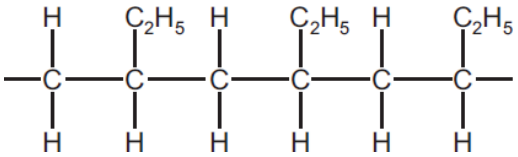
D



D



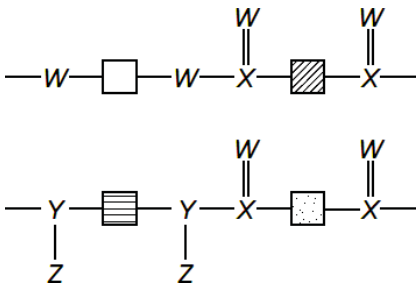
43 The diagram shows a section of a polymer.



Which alkene is used to make this polymer?

A $CH_3CH=CH_2$
B $CH_3CH_2CH=CH_2$
C $CH_3CH_2CH=CHCH_2$
D $CH_3CH=CHCH_3$

44 The diagram shows the partial structures of two different polymers.



Which chemical symbols should replace *W*, *X*, *Y* and *Z*?

	W	*X*	*Y*	*Z*
A	C	N	H	O
B	N	H	O	C
C	O	C	H	N
D	O	C	N	H

Organic Chemistry: Hydrocarbon as fuels

45 Octane is an alkane found in petrol.
Which statement about octane is correct?

A It can be polymerised.
B It decolourises aqueous bromine.
C It has a lower boiling point than methane.
D It reacts with chlorine by substitution.

46 Which statement about a petroleum fraction is correct?

A It boils at a fixed temperature.
B Its molecules are all hydrocarbons.
C None of its molecules is found in other fractions,
D Its molecules all contain the same number of carbon atoms.

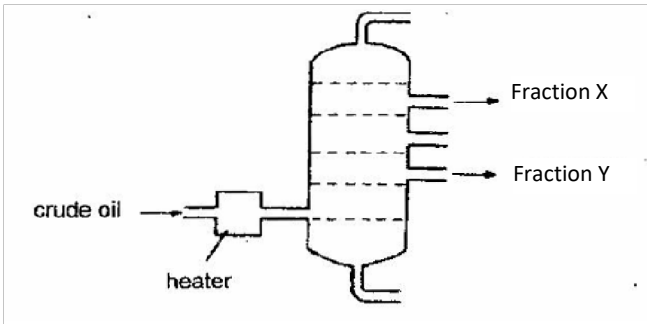
47 Rubber is a hydrocarbon. A tyre for a bus is made by heating together a mixture of rubber and sulfur. What are all the possible products if a piece of the tyre is burnt in air?

A Carbon monoxide, carbon dioxide and water.
B Carbon monoxide, soot and sulfur dioxide.
C Soot, carbon monoxide, carbon dioxide and water.
D Carbon dioxide, carbon monoxide, soot, water and sulfur dioxide.

48 Leaded petrol contains tetraethyllead, $Pb(C_2H_5)_4$. Which of the following is not produced from the combustion of tetraethyllead?

A carbon monoxide
B nitrogen monoxide
C lead(II) oxide
D water vapour

49 The diagram shows the fractional distillation of crude oil.



Which statements about the fractions **X** and **Y** are correct?

	X is more flammable than **Y**	**X** has a higher boiling point than **Y**	**X** is more viscous than **Y**
A	Yes	No	No
B	Yes	Yes	No
C	No	Yes	Yes
D	No	No	Yes

50 When crude oil is distilled, a number of fractions are collected. Which of these statements about the fractions is true?

A The first fraction has the lightest colour.
B The first fraction is a single pure substance.
C The first fraction burns with a lot more soot than last fraction.
D The first fraction has the highest boiling point.

51 Which statement about 'fossil fuel' is true?

I They contain carbon.
II They are renewable.
III They are all in liquid form.
IV They are all made from remains of the ancient trees and plants millions of years ago.

A I and II

B II and III

C III and IV

D I and IV

52 Which of the following petroleum fractions is correctly matched with its application?

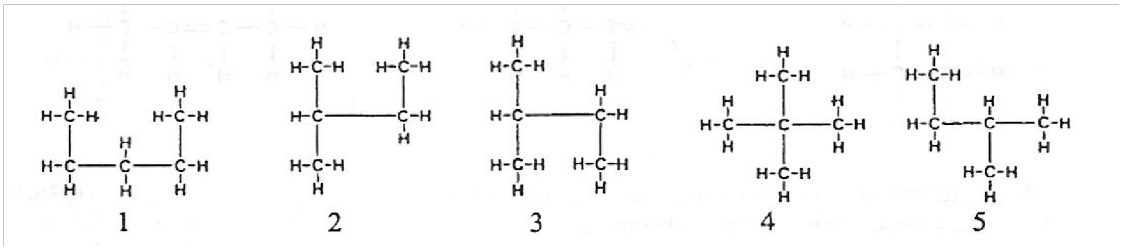
	Fraction	Application
A	naphtha	chemical feedstock
B	bitumen	waxes and polishes
C	kerosene	surfacing roads
D	lubricating oil	fuel for aircraft

53 Which substance, present in car exhaust fumes, is not produced by the combustion of hydrocarbons?

A water vapour
B oxides of nitrogen
C carbon dioxide
D carbon monoxide

Organic Chemistry: Alkane

54 Five structural formulae are shown below.



Which of the following represents 3 different isomeric compounds?

A 1, 2 and 4
B 2, 3 and 4
C 2, 3 and 5
D 1, 2 and 3

ORGANIC CHEMISTRY STRUCTURED QUESTIONS

Paper 2 Section A

1 An alcohol **G** was known to be one of the following.

HOHOCHCH=CHCHOHOH Alcohol **1**

$CH_3CH_2CH_2CH_2OH$ Alcohol **2**

A sample of 1.20 g of alcohol **G** was burned in excess oxygen. 1.79 g of carbon dioxide was formed.

(a) Calculate the mass of carbon present in the sample of alcohol **G**. [1]

Mole of CO2 = 1.79 / (12+16+ 6)
= 0.04068 mo (leave to at least 4 sf in working) Mass of C = 0.04068 mol x 12
0.488 g (3sf)

(b) The mass of hydrogen in the sample is 0.0812 g. Assuming that the rest of the sample is oxygen, calculate the mass of oxygen in the sample. [1]

1.20 – 0.488 – 0.0812 = 0.631 g
[Ecf allow from part (a)]

(c) Use your answers above to find the empirical formula of alcohol **G**. [2]

C : H : O
0.488/ 12 : 0.0812/1 : 0.6 31/16 - [1]
0.0407 : 0.0812 : 0.0394
1 : 2 : 1
Empirical formula is: **CH_2O** - [1]
[Ecf allowed from part (b) and part (a)]

(d) State the identity of alcohol **G**. Explain clearly how you reached this conclusion. [1]

Alcohol G

[1]

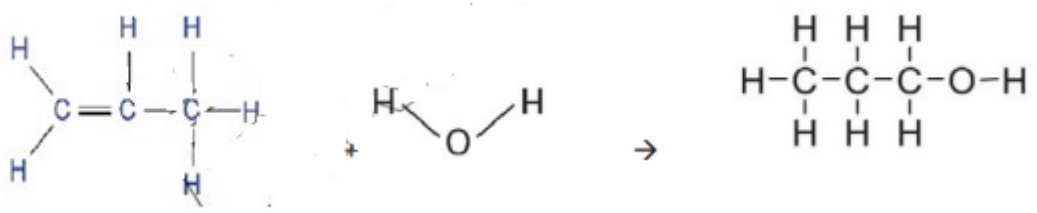
(e) Describe a chemical test to distinguish between alcohol **1** and alcohol **2**. Include expected results in your answer.

Add aqueous bromine to alcohol 1, it deco ouries OR turned from reddish brown to colourless.

From alcohol 2, aq bromine remains reddish brown.Propene can be converted into an alcohol.

(f) Propene can be converted into an alcohol.

Show the **structural equation** for the above reaction. [2]

(f)	 1m – correct structure for propene and water 1m – correct structure for propanol **accept –O-H group to be at second carbon atom]**

[Total: 8]

2 The table shows some information about a homologous series of organic compounds called ketones.

name	number of carbon atoms	formula
propanone	3	CH_3COCH_3
butanone	4	$C_2H_5COCH_3$
pentanone	5	$C_3H_7COCH_3$

(a) Deduce the name and formula of the ketone that contains 6 carbon atoms. [2]

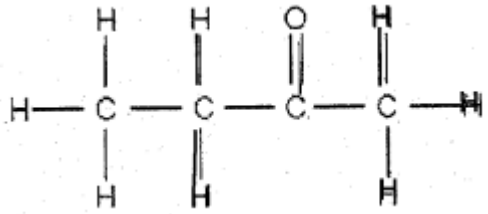
name hexanone

formula $C_4H_9COCH_3$

(a) From **(a)**, deduce the general formula for ketones.

$C_{11}H_{2n+1}COCH_3$ [1]

(b) The oxygen atom in a ketone forms a double bond with a carbon atom. Draw the full structural formula of butanone.



[1]

(c) Separate samples of propanone and propene were placed in separate test tubes and each shaken with bromine water.

Predict what will be seen in each test tube after shaken with bromine water.

Bromine water remains brown in propanone.
Bromine water decolourizes / turns colourless in propene. [2]

[Total: 6 marks]

Paper 2 Section B

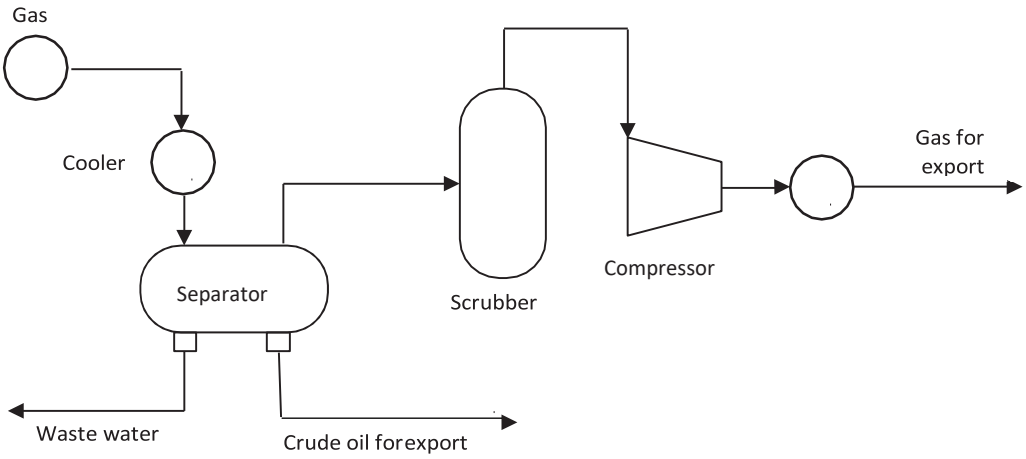
3 Natural gas is a mixture of hydrocarbon compounds formed from the remains of dead plants and animals over a long period of time. It is often found together with other fossil fuels such as crude oil.

An example of components of natural gas is shown in the table.

name	formula	percentage composition / %	boiling point / °C	liquid density / g/cm^3
methane	CH_4	70	- 162	0.423
ethane	C_2H_6	10	- 89	0.546
propane	C_3H_8	10	- 42	0.493
others (carbon dioxide, hydrogen sulfide, etc.)	-	10	-	-

Adapted from: www.naturalgas.org

Natural gas that is extracted from the ground must be purified before it can be used. A simplified diagram showing the process of purification is given in the diagram below. The first step is to cool the mixture and remove water and other dense components like crude oil. The raw gas is then sent to a series of scrubbers, compressors and coolers. Finally, the gas is either compressed or liquefied, and then exported.



Compressed natural gas (CNG) is compressed to 200 to 250 times atmospheric pressure, such that it occupies about 1% of the volume it would otherwise have occupied, and stored in high-pressure tanks. Liquefied natural gas (LNG) is cooled to about -170°C, where it occupies about 1/600th of the volume it would otherwise have occupied, and stored in special insulated tanks.

(a) (i) What is the main component of natural gas?

Methane [1]

(ii) Draw a dot and cross diagram to show the bonding of one molecule of the main component of natural gas stated in **(a) (i).**
You only need to show the outer shell electrons.

[2]

(iii) Explain, using ideas about bonding and structure, why natural gas is volatile.

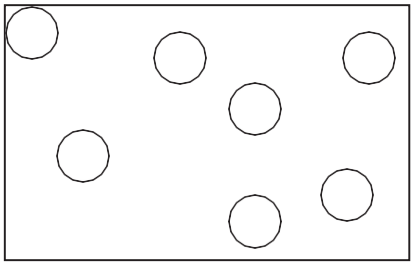
Natural gas is a mixture of covalent compounds which have a simple molecular structure. There are weak intermolecular/ van der Waals forces of attraction between the molecules, [1]
hence little energy must be supplied to overcome these forces of attraction, and natural gas has a low boiling point, which makes it volatile. [1]

[2]

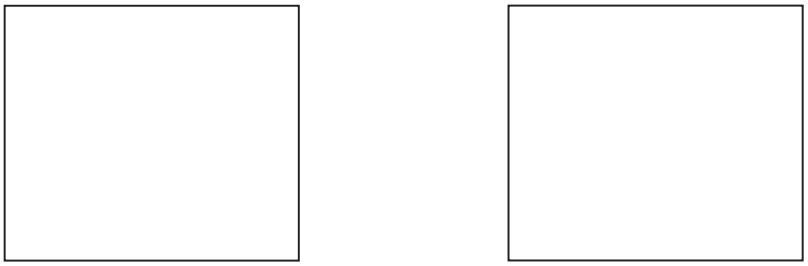
(b) Name a piece of apparatus found in the school laboratory which functions on the similar principle as the separator shown in the diagram.

Separating Funnel [1]

(c) **(i)** The diagram shows the arrangement of particles in natural gas at room temperature and pressure. Draw similar diagrams to show the arrangement of the same number of particles in liquefied natural gas (LNG) and compressed natural gas (CNG).



LNG **CNG**



[2]

(ii) Using the information given, suggest **one** advantage of using liquefied natural gas (LNG) over compressed natural gas (CNG).

Data quoted:

Compared to the original volume of natural gas, LNG occupies **1/600th /0.167%** of the original volume, which is **100 times/ significantly less** than CNG, which occupies **1%** of the original volume. [1]

*Student must quote the data of both CNG and LNG Implication

- Hence
  - LNG is likely to be **easier to transport** than CNG, [1] **OR**
  - fo the same volume, LNG **contains more natural gas** than CNG] **OR**
  - LNG is **safer** to use than CNG because CNG is compressed but LNG is not, hence if a pressurised CNG cylinder is damaged, the danger of an explosion is much greater [1]

1m for comparison of volume/ evidence 1m for stating implication

Accept any reasonable implication of the difference in volume

[2]

[Total: 10]

2 The investigation of hydrocarbons Information 1

From its modest beginning in 1980, the U.S. ethanol industry has grown tremendously in response to surging domestic use and worldwide demand.

The table below shows two different identified processes to produce ethanol.

Process 1	Process 2
Fermentation of a sugar solution by yeast in a reaction vessel. The reaction vessel has to be emptied, cleaned and refilled every few days. The process produces a 15% ethanol solution in water daily.	Reaction of ethene (from crude oil) with steam in a reactor. The reaction is only stopped if there is a fault in the reactor. The process produces 100% pure ethanol.

Information 2

An advertisement for crisps claimed that they are healthier because they are cooked in certain oils. A student found the following information about four oils that are used to make crisps.

	Rapeseed oil	Sunflower oil	Olive oil	Corn oil
Saturated fat / %	6.6	12.0	14.2	14.4
Poly- unsaturated fat / %	29.3	63.3	8.1	51.3
Melting point / ^oC	+5	-18	-12	-15

One hypothesis is that oils are thought to be healthier if they are:

- Low in saturated fat.
- High in poly-unsaturated fat.

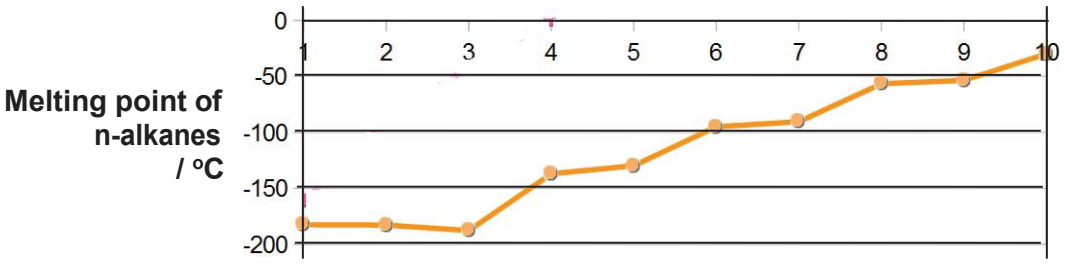
For certain oils and fats such as olive oil, soybean oil, or nut oils, when compared with others, such as margarine, butter, chicken fat and beef fat (the white stuff found in and around slabs of meat), the most prominent difference that was discovered was that different oils and fats have different states of matter at room temperature.

Some oils and fats are liquid at room temperature, and even when kept in the fridge, like olive oil and soybean oil. By contrast, other fats have higher melting temperatures.

The melting point of fats is the temperature at which they become liquid. **Graph 1** shows the change in melting point for saturated hydrocarbon.

Graph 1

Melting point of n-alkanes



The melting temperature is the same as freezing temperature; it is the temperature where the fat changes from a liquid to a solid.

In addition, the effect of the percentage of saturated fats within certain oils on the energy released from combustion was investigated. It was found out that as the saturation of the carbon chain increases, the energy released from combustion decreases.

Table 1: Experimental results on the four different oil used

		Rapeseed oil	Sunflower oil	Olive oil	Corn oil
Energy released from combustion (kJ/g)	Trial 1	5.05	3.48	6.55	3.95
	Trial 2	4.98	3.20	5.98	2.01
	Trial 3	4.46	2.98	6.24	3.88

Table 2: Hydrocarbon table

Name	Chemical formula	Heat of combustion (kJ/g)
Methane	CH_4	55.6
Ethane	C_2H_6	52.0
Propane	C_3H_8	50.0
Butane	C_4H_{10}	49.2

Note: Heat of combustion is also known as enthalpy change. It refers to the heat energy released when a compound undergoes complete combustion with oxygen under a given condition.

(a) Using **Information 1**,

(i) Give one advantage that Process 1 has over Process 2. [1]

Raw materials are renewable / Does not use crude oil

(ii) State one advantage Process 2 has over Process 1 as a manufacturer of ethanol. [2]

Alcohol does not need to be distilled 1] alcohol produced is pure [1]

(b) Using **Information 2,**

(i) Determine which oil should be healthier.

Explain your answer.

The healthier oil is sunflower oil. [1]
It has ess saturated fat than olive oil and corn oil [1] / it has the highest value of polyunsat rated fat compared with all the other oils. [1]
OR

Rap seed oil is healthiest [1] because it has the owest value of saturated fat compared with the other oils. [1] / it has more polyunsaturated fat than both olive and corn oil [1]

(ii) These unsaturated oils can be hardened by an addition reaction with hydrogen at 200 °C with nickel catalyst. [2]

A student said that this hardening process would make sunflower oil healthier.

Is this student's hypothesis correct? Explain your answer.

No, hydrogen adds to the unsaturated fat and redu es the number of carbon carbon double bonds. [1]

Hence there will be polyunsaturated fat [1]

(iii) Using **Table 2**, describe and explain the data patterns for series of heat of combustion on the different alkanes. [2]

Heat of combust on decreases as the number of carbon atom increases. [1]

More bonds are broken during the combustion of longer chain alkanes, hence less energy is released. [1]

(iv) Based on the information given, describe the trend of the melting point of alkanes. [1]

Melting point increases as the umber of carbon atoms increase

[Total: 10]

3 Petroleum is a source of many important chemicals.

(a) Name **two** industrial processes which must take place to produce alkenes from petroleum.

Fractional distill tion [1] and cracking [1] [2]

(b) Ethene and propene can both be converted into polymers.

(i) State the type of polymerisation that takes place when ethene forms a polymer.

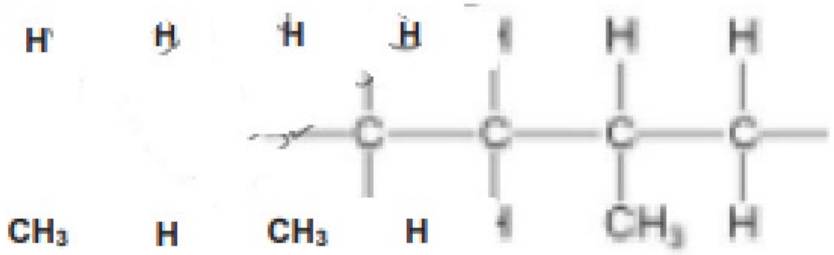
Addition polymerization

[R: Additional polymerization] [1]

(ii) Identify the empirical formula of the polymer formed from ethene.

CH_2 [1]

(iii) Draw **two** repeat units of the polymer made from propene. [2]



[1] chain of 4 carbon atoms with single bonds and continuation bonds;
[1] correctly positioned CH_3 side chains;

(c) Most of the hydrocarbons obtained from petroleum are alkanes. The alkanes are homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}.

Give two characteristics, other than having the same general formula, of members in the same homologous series.

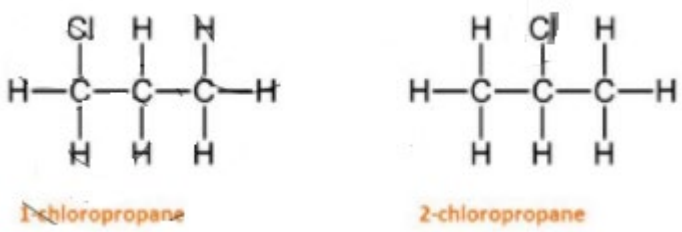
any 2 from

- similar chemical properties
- same functional group

trend each consecutive member differ by CH_2

(d) When one mole of chlorine, Cl_2, reacts with one mole of propane, a mixture of **two** structural isomers is formed in the **first step** of substitution.

Draw **all** the structural formulas of the isomers formed when one mole of chlorine reacts with one mole of propane. [2]

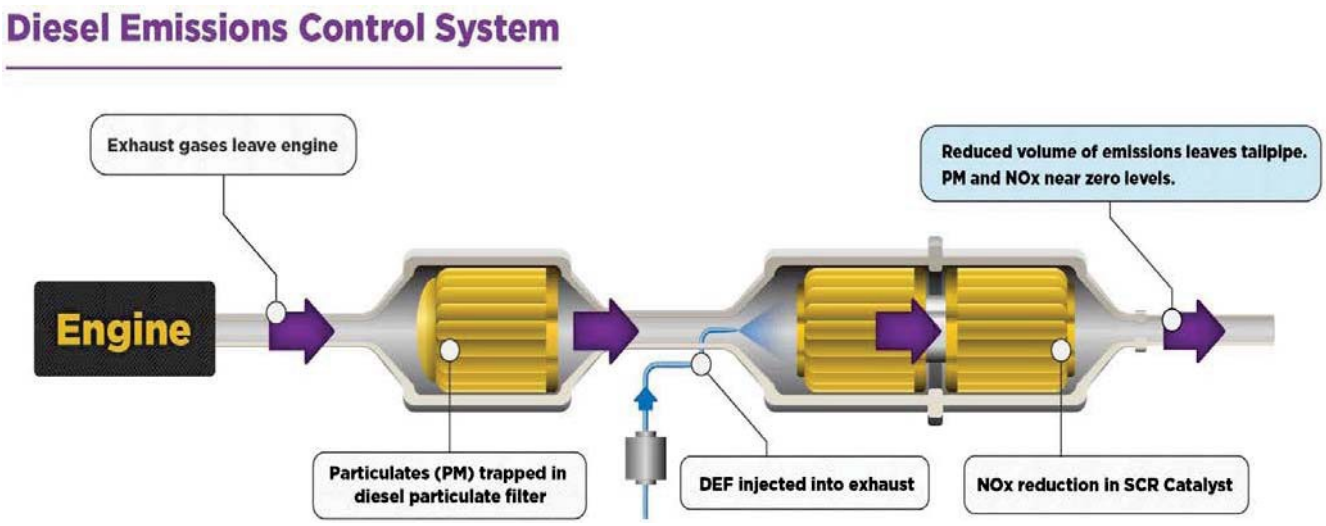


Cl either at first or second carbon atom [Total: 10]

4 Diesel engines can be run with a lean burn air-to-fuel ratio which is larger than that in petrol engine, This is to ensure the full combustion of soot and to prevent them from giving out unburnt fuel. This then leads to generation of oxides of nitrogen (NO_x), which are harmful pollutants, from the nitrogen and oxygen in the air.

Introduction to Diesel Exhaust Fluid (DEF)
Diesel exhaust fluid (DEF) is an aqueous urea solution made with 32.5% by mass of urea, $(NH_2)_2CO$, and 67.5% by mass of deionised water. It is called AUS 32 (aqueous urea solution).

DEF is used in selective catalytic reduction (SCR) in order to lower the concentration of NO_x in the diesel exhaust emissions from diesel engines. Within the SCR catalyst, the NO_x are catalytically reduced by ammonia into water and nitrogen, which are both harmless. These are then released through the exhaust.



Source: http://www.dieselforum.org/about-clean-diesel/what-is-scr

Selective Catalytic Reduction (SCR) systems
SCR catalysts are made from various ceramic materials used as a carrier, such as titanium oxide, and active catalytic components are usually oxides of base metals such as vanadium, molybdenum and tungsten.

The two most common designs of SCR catalyst geometry used today are honeycomb and plate. Each design has different advantages and disadvantages.

	plate-type	honeycomb-type
pressure drop	lower	larger
plugging and fouling	less susceptible	more susceptible
size	large and bulky	smaller
price	expensive	relatively cheaper

**'Plugging and fouling' causes the catalyst to be coated with a layer of unwanted material.*

Reduction of oxides of nitrogen (NO_x)

DEF from a separate tank is injected into the exhaust pipeline. When it is injected into the hot exhaust gas stream, the water evaporates and the urea thermally decomposes to form ammonia and isocyanic acid:

$$(NH_2)2CO(g) \rightarrow NH_3(g) + HNCO(g)$$

The isocyanic acid hydrolyses to carbon dioxide and ammonia:

$$HNCO(g) + H_2O(g) \rightarrow CO_2(g) + NH_3(g)$$

Overall reaction:

$$(NH_2)2CO(g) + H_2O(g) \rightarrow 2NH_3(g) + CO_2(g)$$

From this point, ammonia, in the presence of oxygen and a catalyst, will reduce oxides of nitrogen:

$$2NO(g) + 2NH_3(g) + \frac{1}{2}O_2(g) \rightarrow 2N_2(g) + 3H_2O(g) \text{ and}$$

$$3NO_2(g) + 4NH_3(g) \rightarrow \frac{7}{2}N_2(g) + 6H_2O(g)$$

The overall reduction of nitrogen monoxide by urea is:

$$2(NH_2)2CO(g) + 4NO(g) + O_2(g) \rightarrow 4N_2(g) + 4H_2O(g) + 2CO_2(g)$$

DEF is injected into the exhaust gas at 2–6% of diesel consumption volume.

Storage

It is recommended that DEF be stored in a cool, dry, and well-ventilated area that is out of direct sunlight.

Adapted from: https://en.wikipedia.org/wiki/Diesel_exhaust_fluid
https://en.wikipedia.org/wiki/Selective_catalytic_reduction

(a) Suggest why the running of diesel engines with a lean burn air-to-fuel ratio leads to the production of more oxides of nitrogen.

Lean burn engines uses more air so more nitrogen gas can burn in oxygen; [1]

(b) Suggest why, unlike diesel engines, petrol engines do not require the use of DEF.

Petrol engines produce less soot; petrol is easier to burn completely petrol engines produce less oxides of nitrogen; [1]

(c) Which type of SCR design, honeycomb or plate, is more suitable to be fitted in cars?

Give a reason for your answer.

Honeycomb type as it is smaller;

[1]

(d) State the overall equation for the reduction of nitrogen dioxide (NO_2) by urea.

$2(NH_2)_2\,CO + 3NO_2 \rightarrow \frac{7}{2}\,N_2 + 4H_2O + 2CO_2$ [1]

(e) (i) What is the maximum volume of DEF vapour that needs to be added to 100 dm^3 of diesel vapour?

6dm3 [1]

i. What is the maximum volume of nitrogen gas that can be formed from the combustion of 100 dm^3 of diesel vapour if the DEF injected only contains urea?

12dm3 [1]

(f) State why active catalytic components are usually oxides of metals such as vanadium, molybdenum and tungsten instead of Group I metals.

They are transition metals;

[1]

(g) Suggest why DEF should be stored in a cool area that is out of direct sunlight.

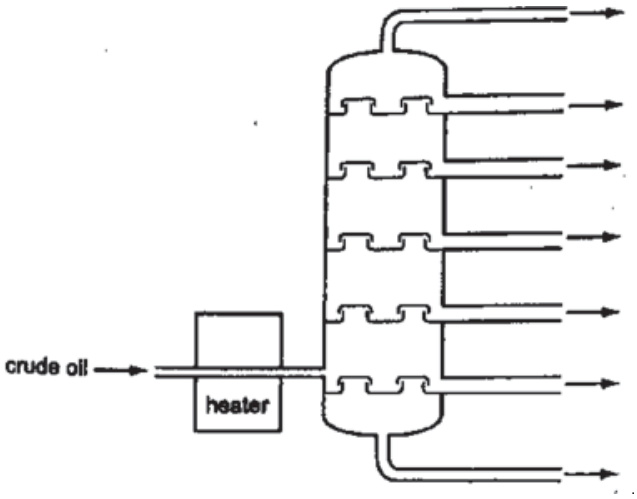
To prevent the decomposition of DEF; [1]

(h) Explain why the use of DEF is not completely environmentally friendly.

It produces carbon dioxide which is a greenhouse gas;
excessive amount leads to global warming which results in melting of polar ice caps [2]

[Total: 10]

5 The diagram below shows how petroleum can be refined.



(a) Briefly describe how fractions can be separated through the fractional distillation of crude oil.

Crude oil enters the heater and is heated up to form a gaseous mixture.;
The gaseous mixture enters the distillation column and is cooled and then separated through condensation
The fractions with the lower boiling points / the lighter fractions will be collected at the top, while the fractions with the higher boiling points / the heavier fractions will be collected at the bottom of the distillation column.;. [3]

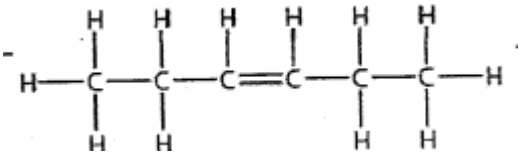
(b) The flow chart below shows how a sweet smelling compound **Y** can be formed from petroleum (crude oil).

(i) Explain why Stage **A** is an important process in the energy industry.

Longer hydrocarbons are cracked to produce shorter hydrocarbons/ smaller molecules (e.g. petrol) that have higher demand in the industries [1]

ii. A long chain alkane, $C_{12}H_{26}$, undergoes Stage **A** to form ethene, butane and an unsaturated compound **Z**.

Draw the structure of compound Z in the space given below.



[1]

[Total: 5 marks]

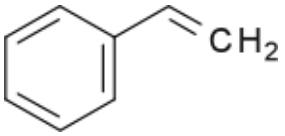
6 Styrene, a liquid hydrocarbon that is important chiefly for its marked tendency to undergo polymerisation.

Styrene is employed in the manufacture of polystyrene, an important plastic, as well as a number of specialty plastics and synthetic rubbers.

Pure styrene is a clear, colourless, flammable liquid that boils at 145 °C and freezes at -30.6 °C.

Unless treated with inhibitor chemicals, it has a tendency to polymerise spontaneously during storage. It is slightly toxic to the nervous system if ingested or inhaled, and contact with the skin and eyes can cause irritation. Although it is suspected of being carcinogenic, studies have not proved it to be so.

The chemical formula for styrene is C_8H_8, but its structural formula, $C_6H_5CH{=}CH_2$, more clearly reveals the sources of its commercially useful properties.



Structural formula of styrene

Styrene is a member of a group of chemical compounds broadly categorised as vinyls—organic compounds whose molecules contain a double bond between two carbon atoms.

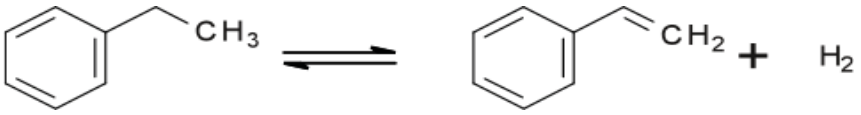
Under the action of chemical catalysts or initiators, this link contributes to the formation of polystyrene, in which thousands of styrene units are linked along a carbon backbone. Hanging from this backbone are phenyl groups (C_6H_5)—large ring-shaped units that interfere with the spontaneous motion of the chainlike polymer and lend polystyrene its well-known rigidity.

The phenyl group is one of the aromatic rings. Styrene, which gives off a penetrating sweetish odour, is therefore one of the aromatic hydrocarbons.

Industrial production from ethylbenzene

The modern method for production of styrene by *dehydrogenation* of ethylbenzene was first achieved in the 1930s. The production of styrene increased dramatically during the 1940s, when it was popularised as a feedstock for synthetic rubber.

Because it is produced on such a large scale, ethylbenzene is in turn prepared on a prodigious scale (by alkylation of benzene with ethylene). Ethylbenzene is mixed in the gas phase with 10–15 times its volume in high-temperature steam, and passed over a solid catalyst bed. Most ethylbenzene dehydrogenation catalysts are based on iron(III) oxide, promoted by several percent potassium oxide or potassium carbonate.



Dehydrogenation of ethylbenzene

Steam serves several roles in this reaction. It is the source of heat for powering the *endothermic* reaction, and it removes coke that tends to form on the iron(III) oxide catalyst through the water gas shift reaction. The potassium promoter enhances this decoking reaction. The steam also dilutes the reactant and products, shifting the position of chemical equilibrium towards products.

A typical styrene plant consists of two or three reactors in series, which operate under vacuum to enhance the conversion and selectivity. Typical per-pass conversions are 65% for two reactors and 70-75% for three reactors. Selectivity to styrene is 93-97%. The main byproducts are benzene and toluene. Because styrene and ethylbenzene have similar boiling points (145 °C and 136 °C, respectively), their separation requires tall distillation towers and high return/reflux ratios. At its distillation temperatures, styrene tends to polymerise. To minimize this problem, early styrene plants added elemental sulfur to inhibit the polymerisation.

During the 1970s, new free radical inhibitors consisting of nitrated phenol-based retarders were developed. More recently, a number of additives have been developed that exhibit superior inhibition against polymerization. However, the nitrated phenols are still widely used because of their relatively low cost. These reagents are added prior to the distillation.

Laboratory synthesis

A laboratory synthesis of styrene entails the decarboxylation of *cinnamic acid*.

$C_6H_5CH{=}CHCO_2H \rightarrow C_6H_5CH{=}CH_2 + CO_2$

Incineration

If polystyrene is properly incinerated at high temperatures (up to 1000 °C) and with plenty of air (14 m^3/kg), the chemicals generated are water, carbon dioxide, and possibly small amounts of residual halogen-compounds from flame-retardants. If only incomplete incineration is done, there will also be leftover carbon soot and a complex mixture of volatile compounds. According to the American Chemistry Council, when polystyrene is incinerated in modern facilities, the final volume is 1% of the starting volume; most of the polystyrene is converted into carbon dioxide, water vapor, and heat. Because of the amount of heat released, it is sometimes used as a power source for steam or electricity generation.

Adapted from: https://www.britannica.com/science/styrene

https://en.wikipedia.org/wiki/Styrene

https://en.wikipedia.org/wiki/Polystyrene

(a) Draw the 'dot and cross' diagram of styrene, showing only the outermost electrons.

[2]

(b) Explain why styrene has a low melting point of -30.6 °C.

……

…… [2]

(c) Explain the type of reaction that occurs in the dehydrogenation process.

…… [1]

(d) Explain why tall distillation towers are necessary for the separation of styrene and ethylbenzene.

……

…… [1]

(e) Draw the repeating unit of polystyrene.

[1]

(f) Write down a balanced chemical equation for the incineration of polystyrene (2 repeat unit) in modern facilitates.

…… [1]

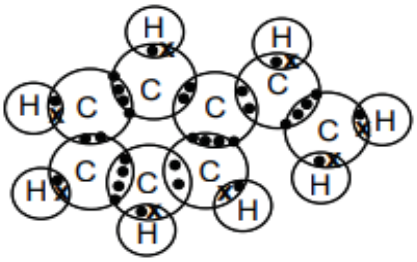
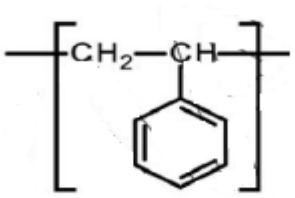
(g) Describe, with a balanced equation, what would be observed when sodium carbonate is put into cinnamic acid.

……

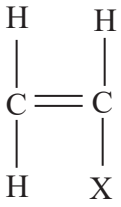
…… [2]

[Total: 10]

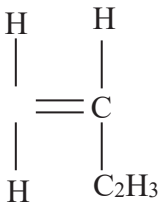
Answer:

6	(a)		2	Dot-and -cross diagram of this compound was shown n la s but students failed to register
	(b)	It is a covalent compound with **weak intermolecular forces** of attraction which **requires little energy to break.**	2	Some students could not answer this basic question
	(c)	Endothermic reaction	1	Badly done. Answer is in the data given
	(d)	They are miscible liquids with very similar boiling points.	1	Most students were ab e to identify that styrene and ethylbenzene have similar boiling points but they failed to mention that they are miscible.
	(e)		1	Many students gave the drawing of the polymer rather than the repeating unit
	(f)	$C_8H_8)_2 + 20O_2 \rightarrow 8H_2O + 16CO_2$	1	Many students wrote the formula of 2 repeating units as $2C_8H_8$ which is wrong. Some even wrote the formula as $C_{16}H_{16}$.
	(g)	Effervescence seen Gas produced forms white precipitate in limewater $2C_6H_5CH=CHCO_2H + Na_2CO_3 \rightarrow 2C_6H_5CH=CHCO_2Na + CO_2 + H_2O$	1 1	Most students were ab e to state the observation but few got the equation correct.

7 **(a)** Styrene-butadiene rubber is a synthetic rubber. It is made by polymerizing a mixture of the monomers butadiene and styrene.



styrene

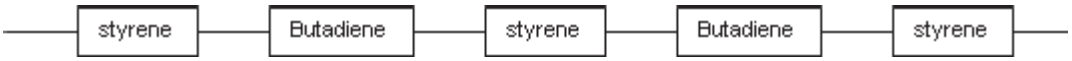


butadiene

(i) What type of polymerisation will take place when the monomers polymerize?

…… [1]

One possible structure for the polymer is shown below.



(ii) Give the full structural formula for the repeating unit in this polymer structure.

[1]

iii. When the mixture of styrene and butadiene polymerizes, the polymer is unlikely to contain only this regular, repeating pattern. Explain why.

……

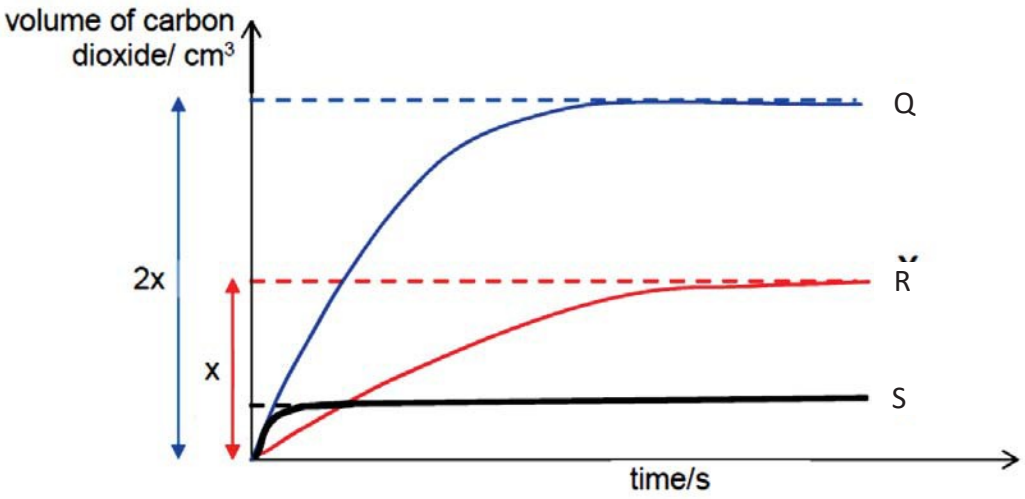
…… [1]

iv. Butadiene is obtained from the cracking of butane. 2.90 kg of butane entered the cracking tower. The percentage yield of butadiene is 75%. Calculate the mass of butadiene obtained from the cracking process.

[1]

b. Three different experiments were carried out using metal carbonates and acids. The table below shows the reactants used in each of the experiment. The graph shows the results of the experiments.

experiment	reactants
Q	150 cm^3 of 2.0 mol/dm^3 H_2SO_4 (aq) + 26.5g Na_2CO_3 (s)
R	v cm^3 of 1.0 mol/dm^3 H_2SO_4 (aq) + excess Na_2CO_3 (s)
S	150 cm^3 of z mol/dm^3 H_2SO_4 (aq) + excess $CaCO_3$ (s)



(i) Identify the limiting reagent in experiment Q.

[2]

(ii) Calculate the volume of carbon dioxide gas produced in experiment R and hence calculate the volume, v cm^3, of sulfuric acid used.

Volume of carbon dioxide = ……..

v =……[2]

(iii) From the graph, deduce the concentration of sulfuric acid used in experiment S.

Concentration of sulfuric acid =

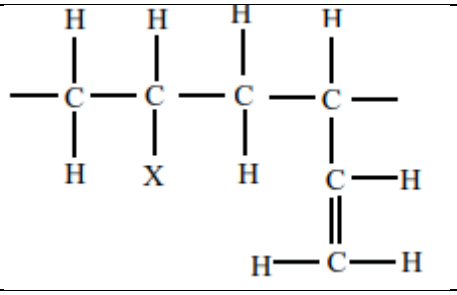
……[1]

b The mass of the salt formed in experiment S is much lower than expected. Write a balanced chemical equation, including state symbols, to suggest another reaction that can prepare a greater mass of this salt.

……[1]

[Total: 10]

Answer:

7	**(ai)**	Addition Polymerisation	1	Not many students attempted this question. Some students wrote “polymerization” as the w
	(ii)		1	Many students drew the structure of the polymer instead of the repeating unit
	(iii)	Poly(styrene) and Poly(butadiene) will be formed as well	1	Many students gave vague answers like “styrene and butadiene will also combine with itself.”
	(iv)	0 75 x 2.9 = 2.175 kg = 2.18 kg	1	Some students were unable to calculate this straight forward question.

	(bi)	$H_2SO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + CO_2 + H_2O$ No. of moles of H_2SO_4 = 150/1000 x 2 = 0.3 No. of moles of Na_2CO_3 = 26.5/ 2(23)+12+3(6) = 0.25 Limiting reagent = sodium carbonate	½ ½ 1	Generally well-answered
	(ii)	No. of moles of carbon dioxide used in experiment Q = 0.25 Volume of carbon dioxide used in experiment Q = 0.25 x 24 = 6 dm^3 Volume of carbon dioxide produced in experiment R = 6/2 = 3 dm^3 No. of moles of sulfuric acid in experiment R = 0.25. Volume of sulfuric acid, v = 0.25/1.0 = **0.25 dm^3 = 250 cm3**	½ ½ 1	Many students were able to calculate the volume of carbon dioxide produced but were unable to calculate the volume of sulfuric acid
	(iii)	2.0 mol/dm^3	1	
	(iv)	$Ca(NO_3)_2$ (aq) + Na_2SO_4 (aq) → $CaSO_4$ (s) + $2NaNO_3$ (aq)	1	

8 **(a)** A student reacted together an alcohol and a carboxylic acid under appropriate conditions to produce an ester.

A sweet smelling organic liquid, **Q**, with the empirical formula C_2H_4O was produced. The M_r of **Q** was found by experiments to be 87.5.

(i) What is the molecular formula of **Q**? Show the necessary calculation. [1]

(ii) In the boxes below, draw the structural formula of **two** isomers with this formula that are **straight chain** esters. [2]

A sample of **Q** was heated with aqueous sulfuric acid. The product obtained was a mixture of the original alcohol and carboxylic acid. This mixture was heated under reflux with acidified potassium manganate(VII) to give a **single** product, **R**.

The product, **R**, was collected and subjected to the following tests:

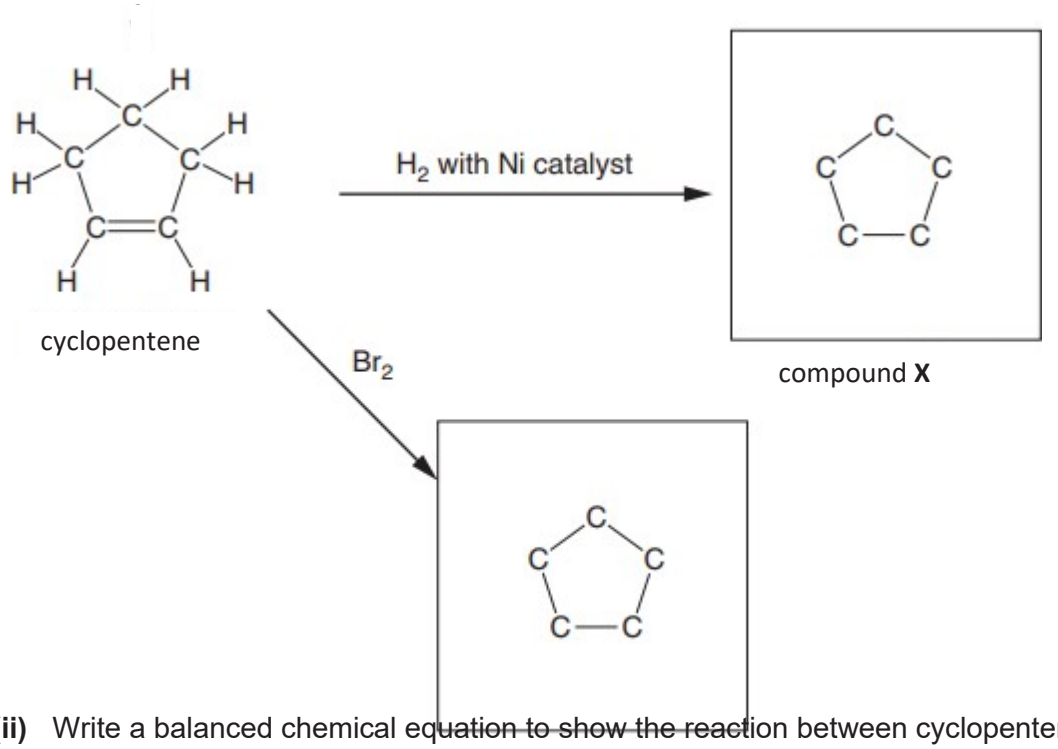
- A sample of **R** gave no reaction with aqueous bromine.
- A second sample of **R** gave an effervescence with sodium carbonate.
- A third sample of **R** is completely miscible with water.

(iii) What is the identity of single organic compound **R**?

..... [1]

(b) Cyclopentene is a cyclic alkene with the formula C_5H_8. It is a colourless liquid with a petrol-like odour. It is used as a monomers for synthesis of plastics.
The figure below shows some reactions involving cyclopentene

(i) Complete the partial structures of compounds **X** and **Y** which are the products of the reactions. [2]



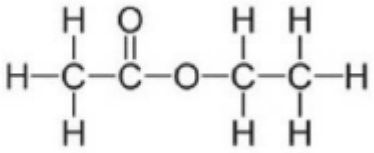
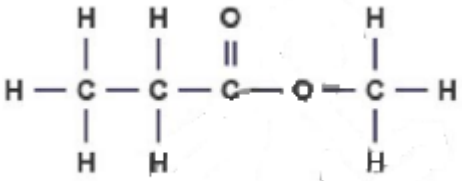
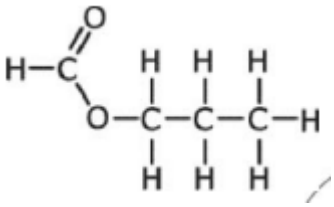
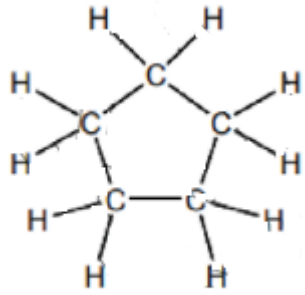
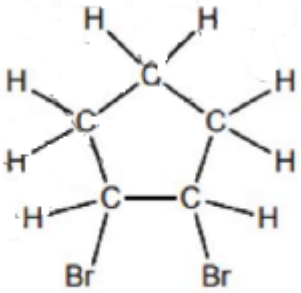
(ii) Write a balanced chemical equation to show the reaction between cyclopentene and aqueous bromine.

..... [1]

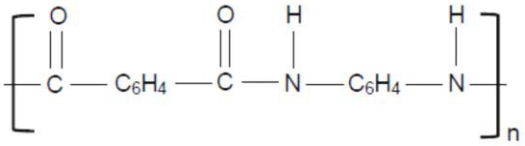
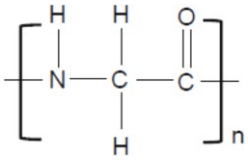
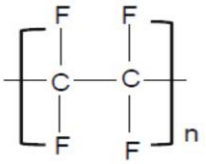
(iii) Cyclopentene can be polymerised to give poly(cyclopentene). Draw a section of poly(cyclopentene) to show two repeat units. [1]

[Total: 8]

Answer:

8	**(ai)**	relative mass of C_2H_4O = 44 Mr ~ 88 N = 88 / 44 = 2 Relative molecular formula is $C_4H_8O_2$	[1]
	(ii)	ethyl ethanoate   **Methyl Propanoate**  **Propyl methanoate** [any 2]	any 2
	(iii)	ethanoic acid	[1]
	(bi)	 Compound X  compound Y [1m for each, all H atoms needed]	[1]
	(ii)	$C_5H_8 + Br_2 \rightarrow C_5H_8Br_2$	[1]
	(iii)	[Must have at least two repeat units and the free bonds at the end. All carbon-carbon bonds in the polymer chain must be shown.]	[1]
			[Total 8]

9 The table below shows some information regarding three materials. They are Kevlar, polyglycine and Teflon.

name of material	structure of polymer
Kevlar	
polyglycine	
Teflon	

(a) Identify the reaction that formed

(i) Kevlar, ... [1]

(ii) polyglycine, ... [1]

(iii) Teflon. ..... [1]

(b) During polymerisation to form Kevlar and polyglycine, hydrogen chloride and water are released respectively.

Draw the structure of the monomer(s) that formed

(i) Kevlar,

[2]

(ii) polyglycine.

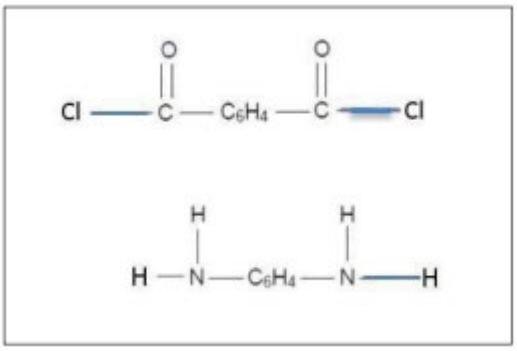
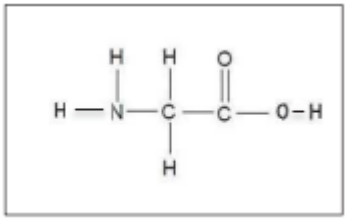
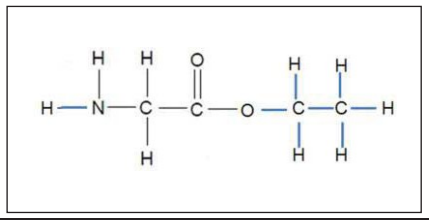
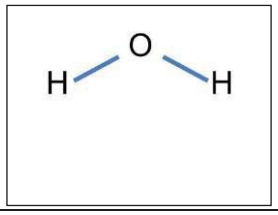
[1]

(c) Suggest the structural formulae of the products formed from a reaction between glycine and ethanol.

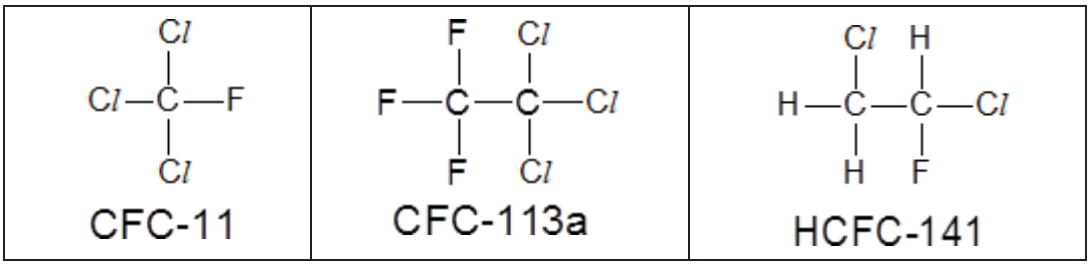
[2]

[Total: 8]

Answer:

9	**(ai)**	condensation polymerisation	[1]
	(aii)	condensation polymerisation	
	(aiii)	addition polymerisation	
	(bi)		[1] [1]
	(bii)		[1]
	(c)	 	[1] for each

10 Chlorofluorocarbons (CFCs) are inert on the Earth's surface. However in the stratosphere, they are very reactive. CFCs are part of a group of compounds which can be classfied as ozone depleting compounds. Other than CFCs, there are also hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs) and perfluorocarbons (PFCs). Some common examples of CFC and HCFC molecules are shown below with their names.



A naming system for these substances was devised several decades ago. The prefixes to the name tell us the elements present in the compound as shown in the table below.

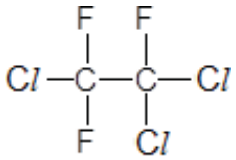
prefix	elements present
PFC	carbon, fluorine
CFC	carbon, fluorine, chlorine
HFC	hydrogen, carbon, fluorine
HCFC	hydrogen, carbon, fluorine, chlorine

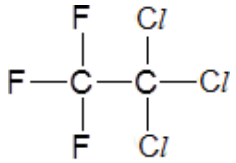
The numbers suffixed to the names of the compounds give us the number of each type of atom present in one molecule of the compound. The key to decoding the number is simply to add 90 to the number suffixed to the name.

.

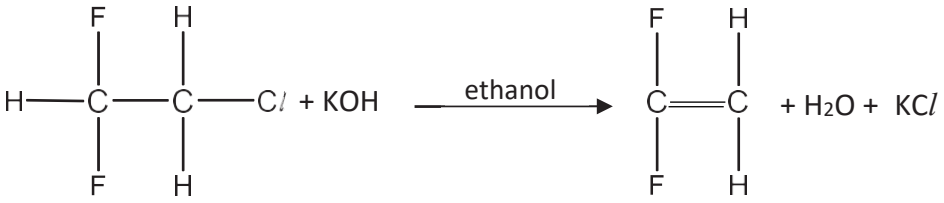
For example, to decode the number of atoms in CFC-113a, we add 113 to 90 to obtain 203. The first number, 2, tells us the number of carbon atoms, the second number, 0, tells us the number of hydrogen atoms, and the third number, 3, tells us the number of fluorine atoms. Chlorine atoms make up the remaining bonds since all these compounds are saturated.

The letter 'a' in CFC-113a tells us about the structural formula of the compound. The arrangement of the type of atoms in the compound that most evenly distributes atomic masses has no letter. The second most even distribution is given the letter 'a', the third most even distribution is given the letter 'b', so on and so forth.

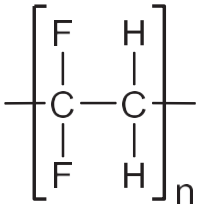
molecule	atomic mass on left carbon	atomic mass on right carbon
 CFC-113	73.5	90

 CFC-113a	57	106.5

Although most of these substances are harmful to the ozone layer, they can also be used to make polymers by first converting them to alkenes. For example, HCFCs react with potassium hydroxide which is dissolved in ethanol (solvent) to give an alkene, potassium chloride and water. An example of the reaction is shown below.



The alkene produced from the above reaction can be used to make useful polymers such as the one shown below.



(a) Draw the structure of a PFC molecule with two carbon atoms. [1]

(b) Copy the table below and draw the other two isomers of HCFC-141 in the correct respective boxes. [2]

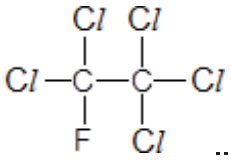
HCFC-141a	HCFC-141b

(c) A student comments that HFCs are safer alternatives to CFCs as HFCs do not harm the environment like CFCs do.

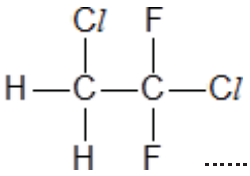
Explain why the student is correct.

..... [1]

(d) Use the naming system discussed in the passage, write down the names of the following molecules.

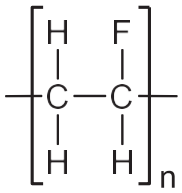
(i) 

..... [1]

(ii) 

..... [2]

(e) **(i)** A scientist wants to produce the polymer, polyvinyl fluoride, using HCFCs.



polyvinyl fluoride

Using a suitable HCFC, write down **two** equations showing the reactions he has to carry out to produce polyvinyl fluoride. Show the structures of all the organic compounds in your equations. [3]

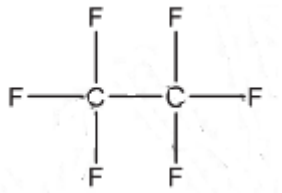
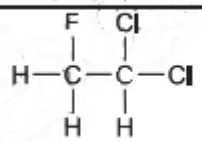
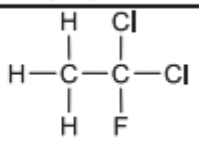
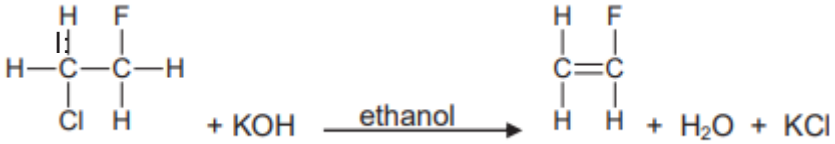
(ii) Samples of the polyvinyl fluoride polymer produced were analysed and found to have a maximum relative molecular mass of 12000.

What is the maximum number of repeating units for this polymer?

..... [2]

[Total: 12]

Answer:

10	**(a)**		[1]
	(b)	HCFC-141a:  HCFC-141b:  [1] for each box	[2]
	(c)	HFCs do not contain chlorine atoms which will deplete the ozone layer.	[1]
	(di)	CFC-111	[1]
	(dii)	HCFC-132a Note: 1 mark for 132, 1 mark for a	[2]
	(ei)	 1 mark for correct HCFC used; 1 mark for equation.	[2]
		II: 	[1]
	(eii)	Mr of repeating unit: 12 x 2 + 19 + 1 x 3 = 46 No. of repeating units: 12000/46 = 260 (round down)	[1] [1]

11 The general structure of an amino acid is given below:

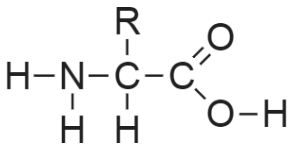


Figure 8.1

where R could just be a simple hydrogen atom or a functional group such as amino or carboxyl group.

The structure below gives a segment of a polypeptide chain with 2 amino acid residues, one with an amino group and another one with a carboxyl group for their R group, when placed in a solution with a pH of 7.

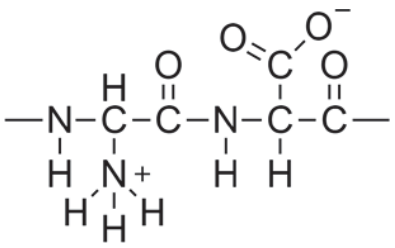


Figure 8.2

(a) Use the structures in Figures 8.1 and 8.2 to explain why

(i) an amino acid is said to be *amphoteric*; and

.....

.....

.....[2]

(ii) a polypeptide chain is said to be a *condensation polymer*.

.....

.....

.....[2]

(b) A protein molecule is formed by one or more polypeptide chains interacting and folding into a three-dimensional structure.

At extreme pH values, this three-dimensional structure of the protein would be altered, causing the molecule to denature and lose its function.

With reference to Figure 8.2, suggest why the shape of the molecule would be altered at different pH values.

.....

.....

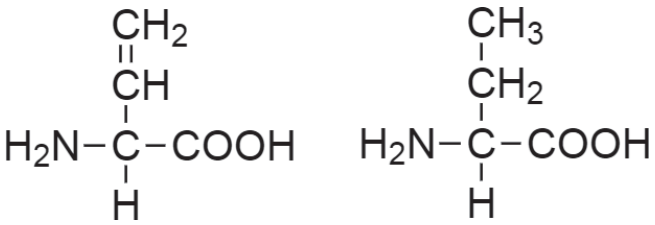
.....

.....[3]

(c) Name a synthetic polymer with similar linkage to polypeptides.

.....[1]

(d) You are given two bottles of solution, each containing a different amino acid as shown in Figure 8.3.



amino acid **J** amino acid **K**

Figure 8.3

Describe a simple chemical test to distinguish between these two amino acids, **J** and **K**.

.....

.....

.....[2]

[Total: 10]

Answer:

11	**(ai)**	The amino group is able to gain hydrogen ion to act as a base; the carboxyl group is able to lose hydrogen ion to act as an acid;
	(aii)	It is formed when many small molecules link together to form a long-chained molecule; without the loss of a small molecule
	(b)	At low pH, the polypeptide chain may gain hydrogen ions and become positively charged; At high pH, the polypeptide chain may lose hydrogen ions and become negatively charged; The change in the charges would affect the electrostatic interactions within the molecules;
	(c)	Nylon
	(d)	Add aqueous bromine to a sample of each. Amino acid J will turn red-brown aqueous bromine colourless; amino acid K will not cause a change in colour in aqueous bromine

12 Fats and oils are triglycerides formed from the condensation reaction of propane-1,2,3-triol with long chain carboxylic acids (fatty acids). Each triglyceride is formed from three fatty acids.

Fig. 8.1 shows the structural formula of a triglyceride likely to be found in peanut oil.

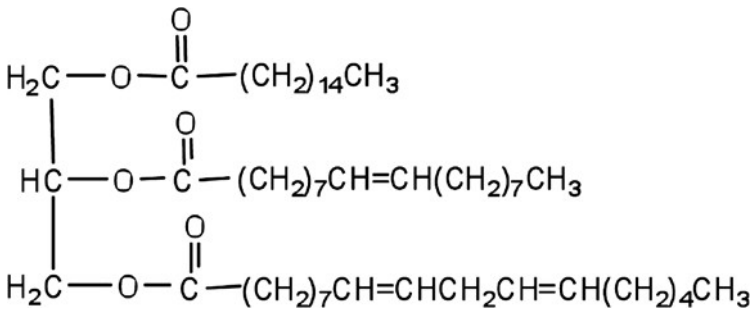


Fig. 8.1

A triglyceride is considered a fat if it is a solid at 25°C, whereas it is considered an oil if it is a liquid at 25°C. These differences in melting points reflect the differences in the degree of unsaturation and molar mass of the constituent fatty acids.

One method for checking the unsaturation level in fatty acids is to determine the iodine number. *Iodine number* is the number of grams of iodine consumed by 100 g of fat or oil. A higher iodine value indicates a higher degree of unsaturation.

Table 8.2 shows average figures for the percentage fatty acid composition of some common fats and oils.

Table 8.2

source of fat or oil	% saturated fatty acids (total)	% monounsaturated fatty acid, oleic acid ($C_{17}H_{33}COOH$)	% polyunsaturated fatty acids	
			linoleic acid ($C_{17}H_{31}COOH$)	linolenic acid ($C_{17}H_{29}COOH$)
beef fat	59	38	3	—
coconut oil	90	8	2	—
corn oil	25	26	47	2
cotton seed oil	22	35	43	—
olive oil	15	78	7	—
soybean oil	14	28	50	8

The *polyunsaturated/saturated (P/S) index* of a fat or oil is the ratio of polyunsaturated fat to saturated fat. It is sometimes used to compare the relative health benefits of different fats and oils in the diet.

The above passage is modified from https://2012books.lardbucket.org/books/introduction-to-chemistry- general-organic-and-biological/s20-lipids.html.

(a) (i) State the chemical linkage which is observed in Fig. 8.1.

…… [1]

(ii) Identify the by-product formed for the reaction of propane-1,2,3-triol with three long chain carboxylic acids (fatty acids).

…… [1]

(iii) Draw the structural formulae of **two** reactants that are used to produce the triglyceride, as seen in Fig. 8.1.

- reactant 1: propane-1,2,3-triol

- reactant 2: one of the carboxylic acids

[2]

(b) Using the information in Table 8.2, deduce and explain which fat or oil has the lowest iodine number.

……

…… [2]

(c) Although cotton seed oil and corn oil have similar iodine numbers, the melting point of cotton seed oil is higher than that of corn oil.

Suggest an explanation, in terms of the structure and bonding, in these two oils.

……

……

……

……

…… [2]

(d) Linoleic acid is a polyunsaturated fatty acid with molecular formula of $C_{17}H_{31}COOH$.

How many double bonds between carbon atoms are present in one molecule of linoleic acid? Explain your reasoning.

……

……

……

……

…… [2]

(e) A P/S value of greater than 1 is considered beneficial for health.

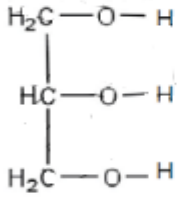
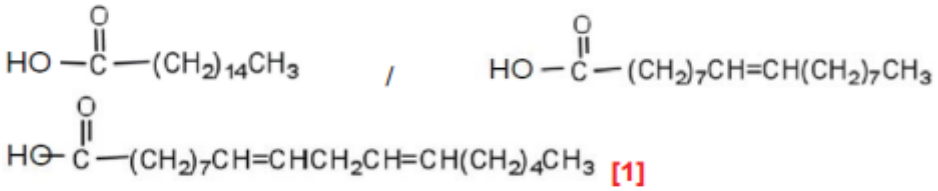
Calculate the P/S index of coconut oil and soybean oil, giving your answers to 3 significant figures.

Hence, determine which oil, coconut oil or soybean oil, is more beneficial for health.

…… [3]

[Total: 13]

Answer:

12	**(ai)**	Ester linkage	[1]
	(aii)	Water / H_2O	[1]
	(aiii)	Structural formula of propane-1,2,3-triol:  [1] Structural formula of one of the carboxylic acids:  [1]	
	(b)	Coconut oil as the percentage of unsaturation adds up to (8% + 2% =) 10% which is the lowest	[1] [1]
	(c)	NOTE: Since cotton seed molecules and corn oil molecules have similar iodine numbers, their <u>melting points is not dependent on the degree of unsaturation</u>. Cotton seed oil (molecules) have higher molar mass / relative molecular mass than corn oil (molecules) More energy is needed to overcome the stronger intermolecular forces / Van der Waals' forces of attraction between the molecules. or Corn oil (molecules) have lower molar mass / relative molecular mass than cotton seed oil (molecules). Lesser energy is needed to overcome the lesser intermolecular forces / Van der Waals' forces of attraction between the molecules. Reject: the phrase 'bonds' in replacement of 'forces', 'break' in replacement of 'overcome', and 'atoms' in replacement of 'molecules'	[1] [1]
	(d)	Since general formula of carboxylic acid is $C_nH2_{n+1}COOH$, a saturated fatty acid with 18 carbon atoms should have a molecular formula of $C_{17}H_{35}COOH$. Since a decrease in 2 hydrogen atoms indicates the present of one carbon-carbon double bond in each molecule, each molecule of linoleic acid ($C_{17}H_{31}COOH$) will contain two carbon-carbon double bonds	[1] [1]

	(e)	P/S of coconut oil = $\frac{2}{90}$ = 0.0222 (3 sig. fig.) P/S of soybean oil = $\frac{50+8}{14}$ = 4.14 (3 sig. fig.) Soybean oil is more beneficial for health than coconut oil	[1] [1] [1]

13 Dieticians recommend that saturated fats in our diet be replaced by polyunsaturated vegetable oils. Vegetable oils can often be converted by reacting with hydrogen through a process called hydrogenation.

(a) (i) Define the term 'polyunsaturated'

The term polyunsaturated refers to the presence of two or more / more than one carbon−carbon double bonds / C=C bonds or carbon−carbon triple bonds / C≡C bonds in a molecule. **[1]**

(ii) What type of reaction is hydrogenation?

Addition [1]

(iii) Name a catalyst needed for the reaction in **(b) (i).**

Nickel **[1]**

(iv) 10.0 g of an oil (M_r = 800) is completely reacted with 1.80 dm^3 of hydrogen measured at r.t.p.

Calculate the number of moles of hydrogen that will react with one mole of the oil. Hence deduce the number of C=C bonds present in each molecule of the oil.

No. of mol of oil = 10.0 ÷ 800 = 0.0125

No. of mol of hydrogen gas used = 1.80 ÷ 24 = 0.0750

0.0125 mol of oil needed 0.0750 mol of hydrogen gas

1 mol of oil will need 0.0750 ÷ 0.0125 = 6 mol of hydrogen gas

Therefore, the oil has 6 C=C bonds per molecule.

(b) In the table below, state the IUPAC name of the ester that is formed using each corresponding pair of alcohol and carboxylic acid.

	alcohol	carboxylic acid	ester
(i)	propan-1- ol	ethanoic acid	propyl ethanoate
(ii)	butan-1-ol	propanoic acid	butyl propanoate

[2]

14 The following is a list of formulae of organic compounds.

C_2H_5OH C_3H_8 C_4H_8 C_5H_{10} $C_5H_{11}COOH$

(a) (i) State the compounds that belong to the same homologous series. [2]

C_4H_8, C_5H_{10}

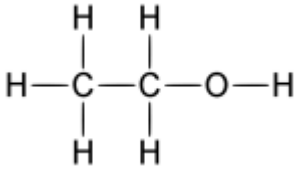
(ii) Name the homologous series. [1]

alkenes

(b) List all the non-hydrocarbons. [2]

C_2H_5OH, $C_5H_{11}COOH$

(c) Draw the full structural formula for C_2H_5OH. [1]



(d) Write the condensed structural formula for C_3H_8. [1]

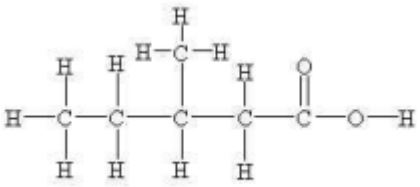
$CH_3CH_2CH_3$

(e) $C_5H_{11}COOH$ can exist as four isomeric compounds.

(i) Complete the IUPAC name of one of the isomers. [1]

3-methyl_3-methylpentanoic acid

(ii) Draw the full structural formula of the isomer. [1]

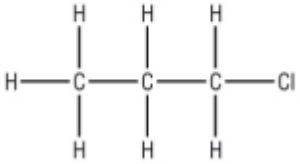
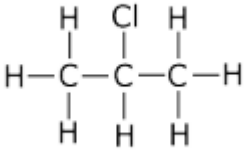


15 When propane reacts with chlorine, two different monosubstituted propanes are produced.

(a) State the condition(s) needed for the reaction. [1]

presence of ultraviolet light / sunlight, excess propane

(b) Draw the structural formula of each of the two isomeric products and give its IUPAC name. [4]

Structural formula	IUPAC name
	1−chloropropane
	2−chloropropane

16 The following is a list of formulae of organic compounds.

CH_3COOH C_5H_{12} C_2H_5OH C_3H_6 C_7H_{14}

Which of the above formulae fit the following descriptions?

(a) A compound which dissolves to form an acidic solution [1]

CH_3COOH

(b) A compound which is not a hydrocarbon. [1]

Either CH_3COOH or C_2H_5OH

(c) Two compounds which are from the same homologous series. [1]

Either CH_3COOH or C_2H_5OH

(d) Two compounds which react to form an ester. [1]

CH_3COOH and C_2H_5OH

(e) A compound which undergoes an addition reaction with steam. [1]

C_3H_6 or C_7H_{14}

17 Olive oil contains oleic acid which is unsaturated.

(a) By naming the reagent and giving the observation, describe a simple test to confirm that olive oil contains an acid. [2]

Add carbonate and test for CO_2
[1] Observation: Effervescence observed, colourless, odourless gas produced which produces a white precipitate when passed through limewater.
[1] (or named suitable metal with test for H_2 gas

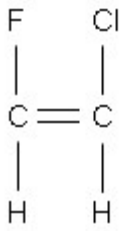
(b) Explain what is meant by the term "unsaturated" [1]

An unsaturated molecule contains at least one or more C=C bond

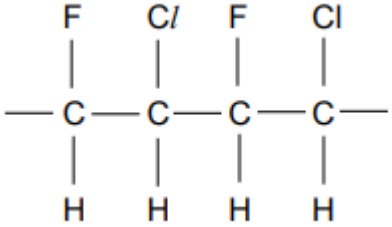
(c) By naming the reagent and giving the observation, describe a simple test to confirm that oleic acid is unsaturated.

Add liquid bromine / aqueous bromine Reddish-brown bromine is rapidly decolourised/ bromine changes from reddish brown to colourless

18 The structure of chlorofluoroethene is shown below:



(a) Name and draw the structure of the macromolecule formed when chlorofluoroethene polymerises [2]



[1] for correct structure (at least 2 repeat units shown)

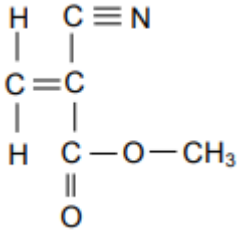
(b) When 20.5 tonnes of chlorofluoroethene is polymerized, 18.5 tonnes of the polymer were obtained. Calculate the percentage yield. [1]

% yield = 18.5 ÷ 20.5 x 100% = 90.2%

(c) Name and give the use for a commercially available polymer containing a halogen. [2]

Name : poly(vinylchloride) or poly(chloroethene) Use: making water pipes, raincoat, etc
Teflon or poly(tetrafluoroethene) Use: non stick coating in pots etc.
(or any other suitable answer)

19 **(a)** 'Superglue' contains the following monomer:

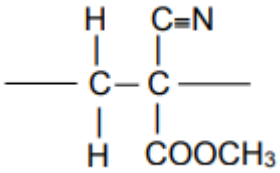


The monomer is rapidly polymerised by traces of bases on the surfaces of objects to be stuck together, causing the glue to solidify.

(i) What type of polymerisation takes place when the glue is in use? [1]

addition (polymerization)

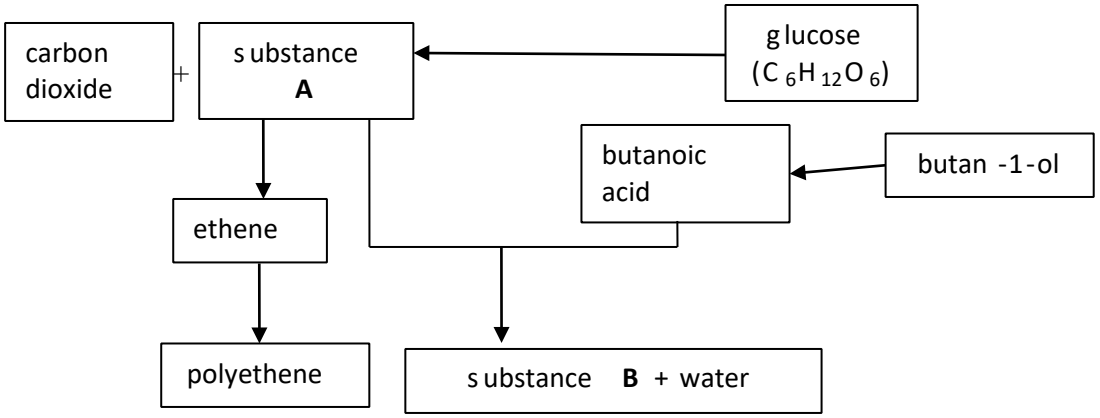
(ii) Draw a repeat unit of the polymerised form of the glue. [1]



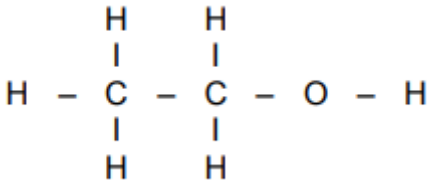
(iii) Calculate the percentage by mass of carbon in the polymer. [1]

$$\% \text{ by mass of carbon} = \frac{5 \times 12}{(5 \times 12) + (5 \times 1) + (2 \times 16) + 14} \times 100$$
$$= 54.1\%$$

20 Glucose undergoes fermentation as shown in the following diagram:



(a) Draw the full structural formula of substance **A** and state its IUPAC name. [2]

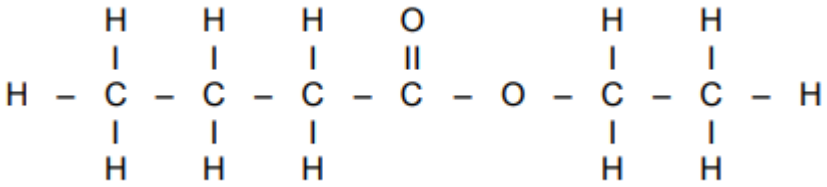


IUPAC name: _____ethanol_____

(b) Give the conditions and reagents required for the formation of substance **A** from glucose. [2]

Yeast, absence of oxygen 37 °C

(c) **(i)** Substance **A** and butanoic acid reacts to form substance **B** and water. Give the IUPAC name and full structural formula substance **B**. [2]



IUPAC name: _____ethyl butanoate_____

(ii) Give two common consumer products which could contain substance **B**. **[2]**

Perfume
Food flavouring
Solvents for cosmetic/deodorant
Nail polish
Bubble gum [Any 2]

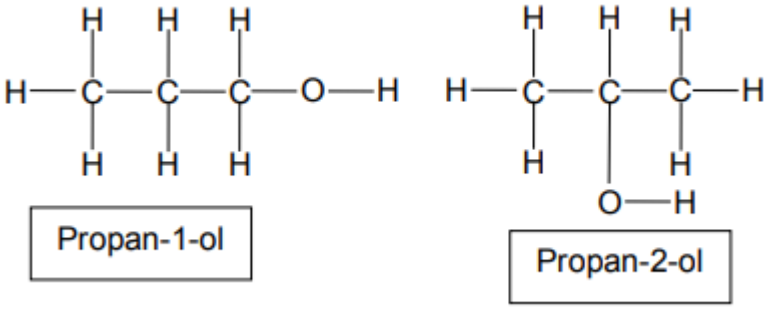
(d) Give the conditions and reagents needed to convert butan-1-ol to butanoic acid. [1]

Reflux/heat with acidified potassium manganate(VII)

21 Ethanoic acid is produced on an industrial scale by the oxidation of ethanol.

(a) Ethanol is a member of the homologous series of alcohols.

(i) State the IUPAC name and draw the structure of the next member of alcohol in the series [2]



IUPAC name : _____Either one is acceptable_____

(ii) Explain why the boiling point of this alcohol is higher than the boiling point of ethanol? [1]

As the molecular size increases, the strength of the van der Waals forces increases, which requires more energy to break, therefore it will have higher boiling point.

(d) (i) Name the product formed when propanoic acid reacts with ethanol. [1]

ethyl propanoate

(ii) Write the equation for this reaction. [1]

$C_2H_5COOH + C_2H_5OH \rightarrow C_2H_5COOC_2H_5 + H_2O$
Or $C_3H_6O_2 + C_2H_6O \rightarrow C_5H_{10}O_2 + H_2O$

22 The table below shows some information about a homologous series of carbon compounds called ethers.

name	number of carbon atoms	formula	boiling point / °C
methoxymethane	2	CH_3OCH_3	−24.8
methoxyethane	3	$CH_3OC_2H_5$	7.0
methoxypropane	4	CH3OC3H7	
	5		70.3

(a) Deduce the name and formula of the ether that contains 5 carbon atoms. [2]

Name : methoxybutane

Formula : $CH_3OC_4H_9$

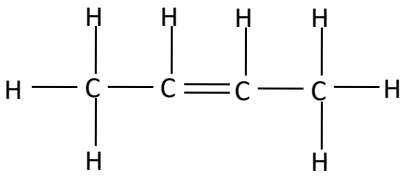
(b) Suggest a value for the boiling point of methoxypropane. [1]

Any value between 35 °C and 43 °C

(c) One of the first anesthetics used to stop pain during surgical operations was ethoxyethane, $C_2H_5OC_2H_5$. It is explosively flammable and so was very hazardous for doctors to use.
Write an equation for the complete combustion for ethoxyethane. [2]

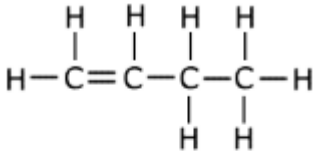
$C_2H_5OC_2H_5 + 6\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$

23 But-2-ene has the structural formula shown below.

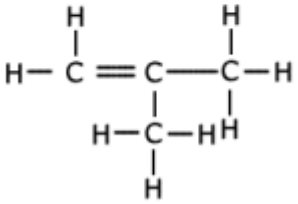


but-2-ene

(d) Draw two isomers of but-2-ene. [2]



but-1-ene

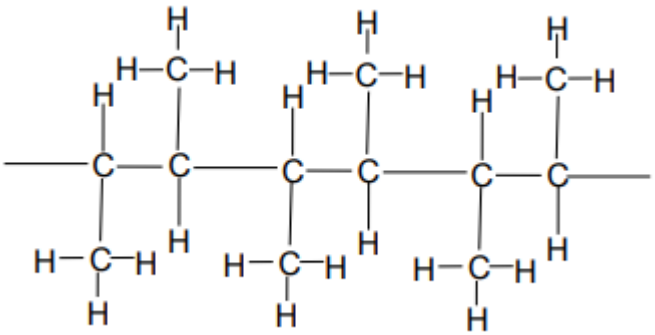


2-methylpropene

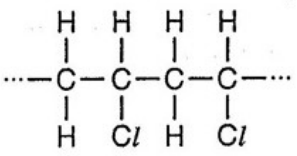
(e) State the type of polymerization that but-2-ene undergoes?
Explain your reasoning. [2]

addition polymerization
This is an addition reaction as the monomers are able to be added to each other across the carbon−carbon double covalent bond.

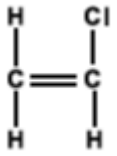
(c) Give the full structural formula of the polymer formed, showing at least three repeat units. [1]



24 The partial structure of a common plastic, polymer **X**, is represented by 2 repeating units of the polymer as shown. Polymer **X** is formed when monomer **Y** undergoes polymerisation.



(a) Draw the structure of the monomer **Y**, from which it is made. [1]



(b) Name the type of polymerisation that convert monomer **Y** to polymer **X**. [1]

addition polymerisation

(c) Name one disadvantage of using common plastics such as polymer **X.** [1]

Plastics are non-biodegradable and difficult to dispose.

(d) Monomer **Y** reacts with steam, in the presence of a catalyst, to form 1-chloroethanol. Name the catalyst used. [1]

phosphoric(V) acid

(e) Another organic compound with the molecular formula, C_4H_8, undergoes reaction with hydrogen gas to form an alkane. Give the conditions and reagents needed for this reaction. [2]

$200^{O}C$
nickel catalyst