CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



EXAM QUESTION PACK

14 HYDROCARBONS

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Chapter 14

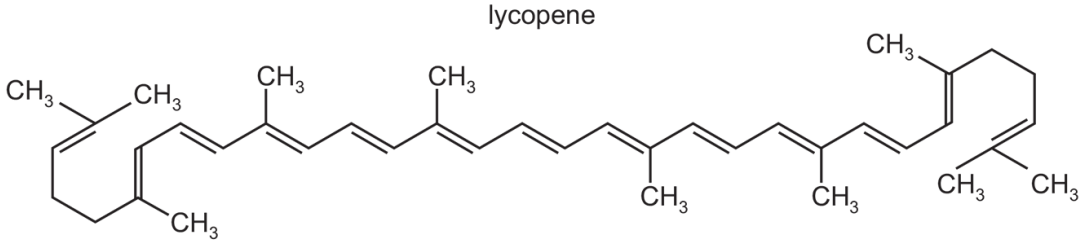
Hydrocarbons

14.1 Alkanes

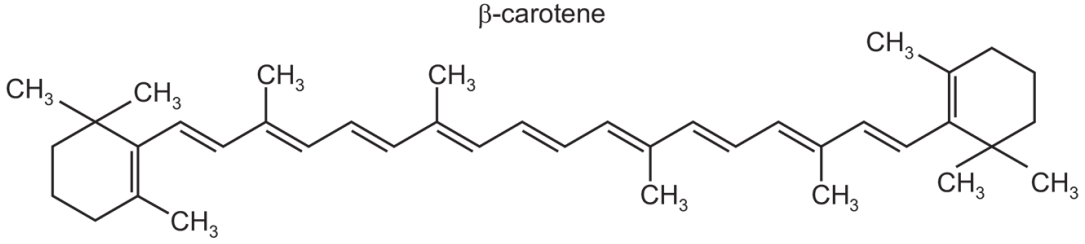
817. 9701_m22_qp_12 Q: 39

The diagrams show the structures of lycopene and β-carotene.

lycopene



β-carotene



When lycopene is converted into β-carotene, what is the gain or loss of hydrogen atoms per molecule?

A 4 gained

B 2 gained

C no change

D 2 lost

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818. 9701_s21_qp_12 Q: 23

Methane and bromine react by free radical substitution.

P and Q are involved in the reaction mechanism.

P and Q:

- are **both** involved in propagation steps as reactants
- are **both** involved in termination steps as reactants.

What could be P and Q?

A Br and H **B** Br and CH_3 **C** Br and C_2H_6 **D** CH_3 and CH_3Br

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819. 9701_w21_qp_12 Q: 21

Bromomethane, CH_3Br, decomposes in the stratosphere forming methyl free radicals and bromine free radicals.

Which row correctly describes this decomposition?

	type of bond fission	number of electrons in a bromine free radical
A	homolytic	35
B	heterolytic	35
C	homolytic	36
D	heterolytic	36

---

820. 9701_w21_qp_12 Q: 23

Which equation represents a valid propagation step in the chlorination of ethane?

A $C_2H_5Cl + Cl\bullet \rightarrow C_2H_4Cl\bullet + HCl$

B $C_2H_6 + Cl\bullet \rightarrow C_2H_5Cl + H\bullet$

C $C_2H_5Cl + H\bullet \rightarrow C_2H_5\bullet + HCl$

D $C_2H_5\bullet + Cl\bullet \rightarrow C_2H_5Cl$

---

821. 9701_s20_qp_12 Q: 19

Most modern cars are fitted with catalytic converters in the exhaust system.

Which three gases are removed by a catalytic converter?

A carbon monoxide, hydrocarbons, nitrogen oxides

B carbon monoxide, carbon dioxide, nitrogen oxides

C carbon monoxide, nitrogen oxides, sulfur dioxide

D hydrocarbons, nitrogen oxides, sulfur dioxide

---

822. 9701_w20_qp_12 Q: 28

Which statement about the use of alkane fuels in internal combustion engines is correct?

A C_8H_{18} is used as fuel in internal combustion engines and reacts with oxygen and nitrogen from the air.

B In limited oxygen, CO is produced which oxidises SO_2 to SO_3 in the atmosphere.

C The catalytic converter removes polluting gases including NO_2 and CO_2.

D Unburnt hydrocarbons and NO_2 can react in sunlight to produce photochemical smog.

---

823. 9701_m19_qp_12 Q: 22

Many reactions take place in the engine and catalytic converter of a car.

Which pair of substances is produced **both** by the reactions in a car engine and in a catalytic converter?

A carbon dioxide and unburnt hydrocarbons

B carbon dioxide and water

C carbon monoxide and nitrogen

D carbon monoxide and unburnt hydrocarbons

---

824. 9701_s19_qp_11 Q: 18

At 550 °C nitrogen dioxide reacts with unburnt hydrocarbon fragments such as CH_3 in the catalytic converter of a motor vehicle.

$$4CH_3 + 7NO_2 \rightarrow 3\tfrac{1}{2}N_2 + 4CO_2 + 6H_2O$$

Which row gives the energy change for this reaction and a possible reason for it?

	energy change of reaction	reason why the reaction is endothermic or exothermic
A	endothermic	chemical energy is converted to heat energy
B	endothermic	the N≡N bond energy is very high
C	exothermic	CO_2 and H_2O have negative $\Delta H_f^{\ominus}$ values
D	exothermic	double bonds are broken in NO_2

---

825. 9701_w19_qp_11 Q: 21

Alkanes are saturated hydrocarbons.

Which type of reaction are alkanes most likely to undergo?

A electrophilic addition

B electrophilic substitution

C free radical substitution

D nucleophilic addition

---

826. 9701_s18_qp_11 Q: 3

Which fuel would produce the largest mass of CO_2 when 10 kg of the fuel undergo complete combustion?

A biodiesel, $C_{17}H_{34}O_2$

B ethanol, C_2H_6O

C octane, C_8H_{18}

D propane, C_3H_8

---

827. 9701_s18_qp_12 Q: 21

Which equation represents a valid propagation step in the chlorination of ethane?

A $C_2H_6 + Cl\bullet \rightarrow C_2H_5Cl + H\bullet$

B $C_2H_5Cl + Cl\bullet \rightarrow C_2H_4Cl\bullet + HCl$

C $C_2H_5Cl + H\bullet \rightarrow C_2H_5\bullet + HCl$

D $C_2H_5\bullet + Cl\bullet \rightarrow C_2H_5Cl$

---

828. 9701_s17_qp_12 Q: 22

Which equation represents the initiation step of the substitution reaction between methane and chlorine?

A $CH_4 \rightarrow CH_3\bullet + H\bullet$

B $CH_4 \rightarrow CH_3^- + H^+$

C $Cl_2 \rightarrow 2Cl\bullet$

D $Cl_2 \rightarrow Cl^+ + Cl^-$

---

829. 9701_s16_qp_11 Q: 23

The **first** propagation step in the reaction between methane and chlorine is shown.

$$CH_4 + Cl\bullet \rightarrow CH_3\bullet + HCl$$

How many different **first** propagation steps are possible in the reaction between pentane and chlorine?

A 2 **B** 3 **C** 4 **D** 5

---

830. 9701_s16_qp_12 Q: 11

Which stage in the free radical substitution of ethane by chlorine has the lowest activation energy?

A $Cl_2 \rightarrow 2Cl\bullet$

B $Cl\bullet + C_2H_6 \rightarrow C_2H_5\bullet + HCl$

C $C_2H_5\bullet + Cl_2 \rightarrow C_2H_5Cl + Cl\bullet$

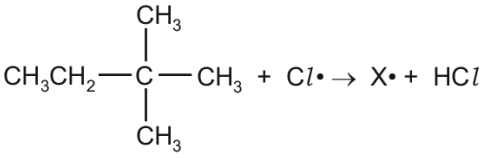
D $Cl\bullet + C_2H_5\bullet \rightarrow C_2H_5Cl$

---

831. 9701_s16_qp_13 Q: 23

When heated with chlorine, the hydrocarbon 2,2-dimethylbutane undergoes free radical substitution.

In a propagation step a free radical X• is formed.



How many different structures of X• are possible?

A 2 **B** 3 **C** 4 **D** 5

---

832. 9701_w16_qp_12 Q: 23

The equation shows a reaction that occurs between carbon monoxide and nitrogen monoxide in a catalytic converter.

$$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$$

Which statement is correct?

A The catalyst used is finely divided iron.

B The reaction prevents greenhouse gas emissions into the atmosphere.

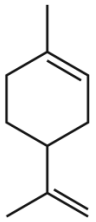
C The reaction reduces the possibility of the formation of photochemical smog.

D The reaction results in increased ozone depletion.

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833. 9701_s15_qp_11 Q: 29

The citrus flavour of lemons is due to the compound limonene, present in both the peel and the juice.



limonene

What is the mole ratio of carbon dioxide to water produced when limonene is completely burnt in oxygen?

	number of moles carbon dioxide	number of moles water
A	4	3
B	5	4
C	5	8
D	9	7

---

834. 9701_w15_qp_11 Q: 22

Crude oil is a mixture of many hydrocarbons ranging in size from 1 to 40 carbon atoms per molecule. The alkanes in crude oil can be separated because they have different boiling points.

The table below shows the boiling points of some alkanes.

alkane	boiling point /°C	M_r
butane	0	58
pentane	36	72
hexane	69	86
2-methylbutane	28	72
dimethylpropane	10	72
2,3-dimethylbutane	58	86

What is the correct explanation for the difference in the boiling points of the three isomers with $M_r = 72$?

A Boiling point is dependent upon the length of the carbon chain **only**.

B Increased branching on a carbon chain increases the boiling point.

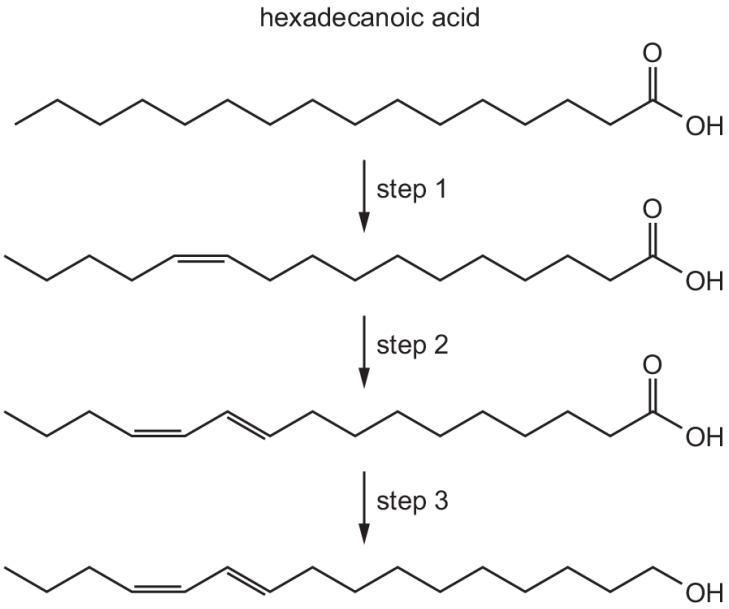
C Increased branching reduces the strength of the intermolecular hydrogen bonding.

D Increased branching reduces the strength of the intermolecular van der Waals' forces.

14.2 Alkenes

835. 9701_s21_qp_12 Q: 21

Hexadeca-10,12-dien-1-ol is produced by silk moths from hexadecanoic acid in a three-step enzymic process.



Which row contains correct descriptions of the three steps?

	step 1	step 2	step 3
A	elimination	elimination	dehydration
B	elimination	reduction	reduction
C	oxidation	elimination	oxidation
D	oxidation	oxidation	reduction

---

836. 9701_s21_qp_13 Q: 21

Two carbon-containing products result from the reaction of alkene Z with a hot, concentrated, acidified solution of potassium manganate(VII).

One product forms an orange precipitate with 2,4-dinitrophenylhydrazine reagent. The other product is a gas which gives a white precipitate with aqueous calcium hydroxide.

Which alkene could be alkene Z?

A but-2-ene

B 2-methylpropene

C 2-methylbut-2-ene

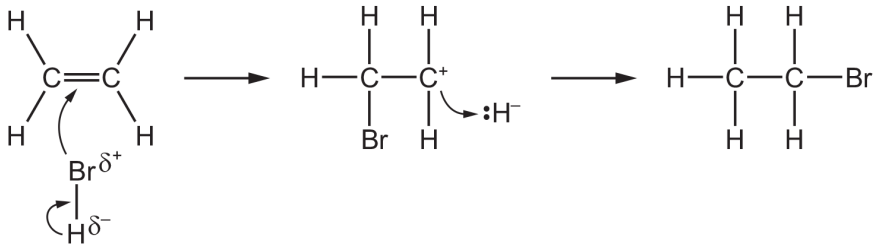
D propene

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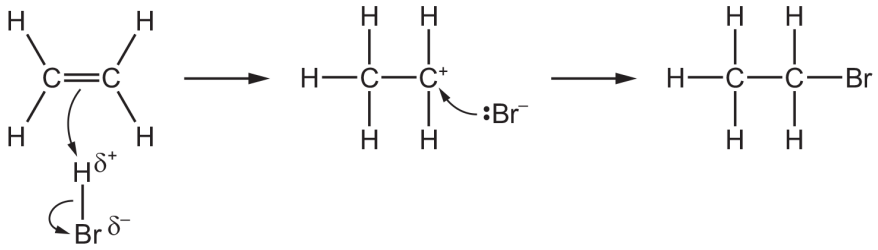
837. 9701_s21_qp_13 Q: 22

What is the correct mechanism for the addition of hydrogen bromide to ethene?

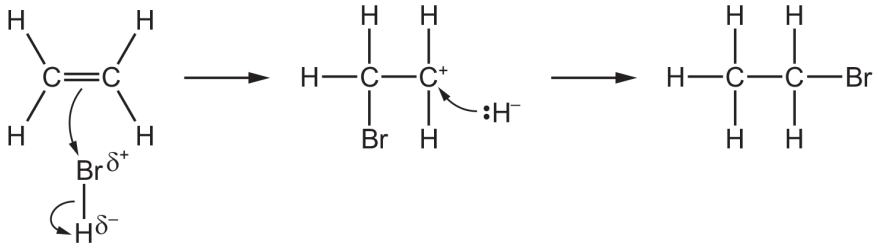
A



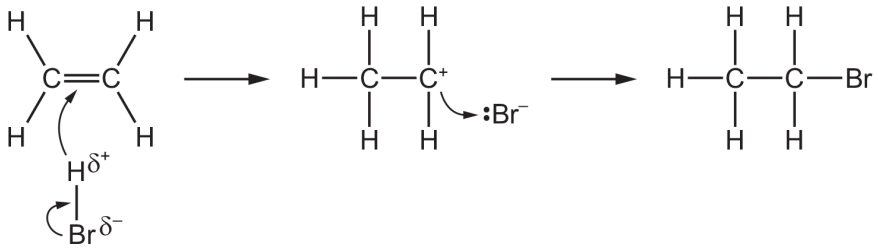
B



C

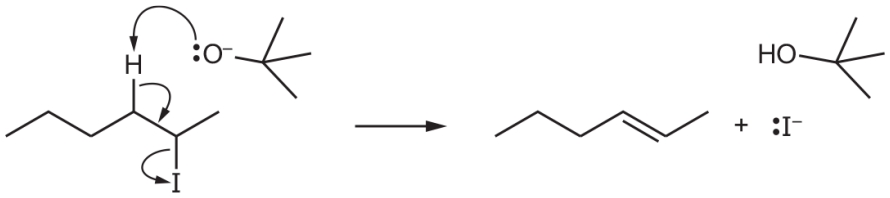


D



838. 9701_w21_qp_11 Q: 20

Hex-2-ene can be made by the reaction shown.



Which statement about this reaction is correct?

A $(CH_3)_3CO^-$ is behaving as a Brønsted-Lowry base.

B $(CH_3)_3CO^-$ is behaving as an oxidising agent.

C The C–I bond breaks via homolytic fission.

D This is a hydrolysis reaction.

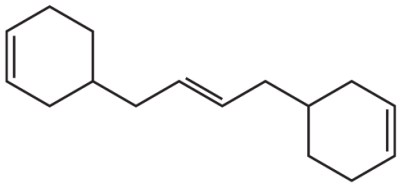
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839. 9701_w21_qp_11 Q: 21

Structural isomerism **only** should be considered when answering this question.

Molecule X contains three C=C double bonds. One mole of X is reacted with three moles of HBr. The carbon skeleton is unchanged.

molecule X



How many different products are formed?

A 3 **B** 4 **C** 6 **D** 8

---

840. 9701_s20_qp_11 Q: 22

But-1-ene and but-2-ene are treated separately with cold, dilute acidified manganate(VII) ions.

Four students, W, X, Y and Z, make statements about these alkenes and the diols formed from them.

W One diol contains two primary alcohol groups.

X One diol contains a primary and a secondary alcohol group.

Y One diol contains two secondary alcohol groups.

Z Both alkenes exhibit *cis-trans* isomerism.

Which two students are correct?

A W and Y **B** W and Z **C** X and Y **D** X and Z

---

841. 9701_s20_qp_11 Q: 24

Poly(propene) is an addition polymer.

What are the C–C–C bond angles along its polymer chain?

A They are all 109°.

B Half of them are 109° and half are 120°.

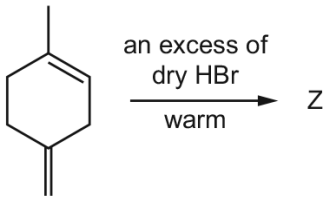
C Half of them are 90° and half are 180°.

D They are all 120°.

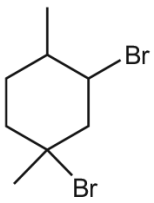
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842. 9701_s20_qp_11 Q: 27

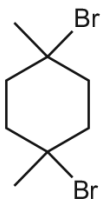
What is the major product Z of the following reaction?



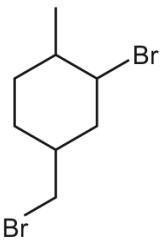
A



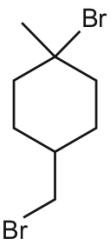
B



C



D



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843. 9701_s20_qp_12 Q: 25

Which substance forms propanoic acid as one of the products when it reacts with hot concentrated acidified potassium manganate(VII)?

A but-1-ene

B but-2-ene

C 2-methylpropene

D 2-methylbut-1-ene

---

844. 9701_s20_qp_12 Q: 28

Ethene reacts with aqueous bromine to give two products, CH_2BrCH_2Br and CH_2BrCH_2OH.

Which statement about these products is correct?

A Both products are obtained in this reaction by nucleophilic substitution.

B Both products are obtained in this reaction by nucleophilic addition.

C Both products can be hydrolysed to form the same organic compound.

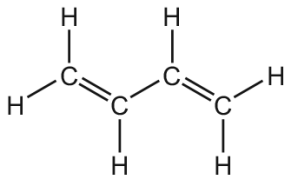
D Both products can form hydrogen bonds with water.

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845. 9701_s20_qp_12 Q: 30

The diagram shows the structure of buta-1,3-diene.

buta-1,3-diene



The addition reaction between buta-1,3-diene and two molecules of hydrogen bromide can produce three structurally isomeric products.

How many of these products have at least one chiral centre?

A 0 **B** 1 **C** 2 **D** 3

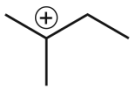
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846. 9701_s20_qp_13 Q: 28

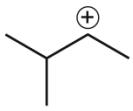
2-methylbut-2-ene reacts with HBr(g) to form two isomeric products. During the reaction two positively charged intermediates can be made.

Which diagram shows the more stable of the two positively charged intermediates?

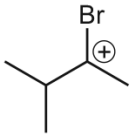
A



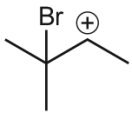
B



C



D



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847. 9701_w20_qp_11 Q: 21

Two students each make a statement about 2-methylbut-1-ene.

Student 1 states that 2-methylbut-1-ene has geometrical isomers.

Student 2 states that 2-methylbut-1-ene reacts with HBr in an addition reaction to give 1-bromo-2-methylbutane as the main product.

Which students are correct?

A both 1 and 2

B 1 only

C 2 only

D neither 1 nor 2

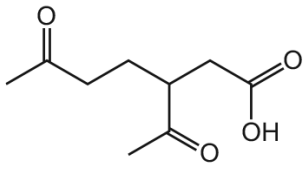
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848. 9701_m19_qp_12 Q: 21

Compound L has the molecular formula $C_{10}H_{16}$.

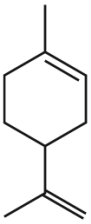
A sample of L reacted with an excess of hot, concentrated, acidified potassium manganate(VII). Compound M is produced.

M

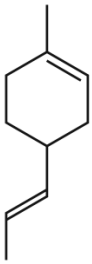


What could be the structure of compound L?

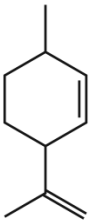
A



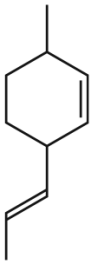
B



C



D



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849. 9701_s19_qp_11 Q: 22

What is the structural formula of the major product when hydrogen bromide reacts with 2-methylbut-2-ene?

A $CH_2BrCH(CH_3)CH_2CH_3$

B $(CH_3)_2CBrCH_2CH_3$

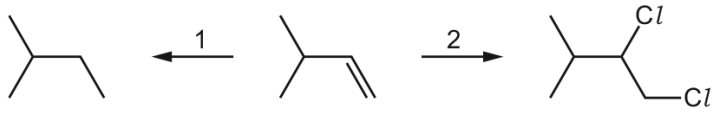
C $(CH_3)_2CHCHBrCH_3$

D $(CH_3)_2CHCH_2CH_2Br$

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850. 9701_s19_qp_12 Q: 20

3-methylbut-1-ene can undergo different types of reaction.



Which row correctly identifies the reaction types?

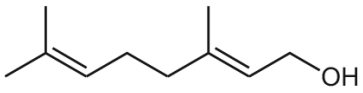
	reaction 1	reaction 2
A	oxidation	electrophilic addition
B	oxidation	nucleophilic addition
C	reduction	electrophilic addition
D	reduction	nucleophilic addition

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851. 9701_s19_qp_12 Q: 23

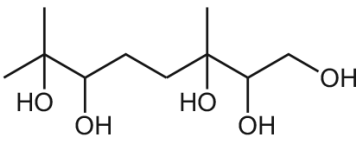
A molecule of geraniol is shown.

geraniol

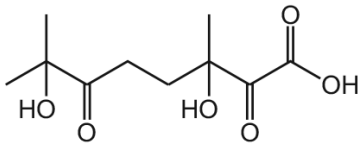


What is formed when geraniol is reacted with an excess of cold, dilute, acidified manganate(VII) ions?

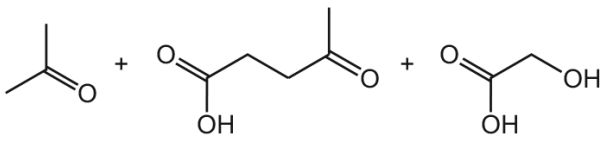
A



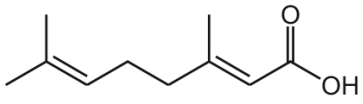
B



C



D



---

852. 9701_s19_qp_12 Q: 26

Propene, bromine and hydrogen bromide are mixed in the dark.

A number of products are formed, some in very small quantities.

Which substance will **not** be present in the mixture of products?

A 1-bromopropane

B 2-bromopropane

C 1,1-dibromopropane

D 1,2-dibromopropane

---

853. 9701_s19_qp_13 Q: 22

In polymer Z every carbon atom in the polymer chain is bonded to one hydrogen atom and one methyl group.

Which alkene could be polymerised to make polymer Z?

A but-1-ene

B but-2-ene

C methylpropene

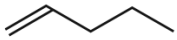
D propene

---

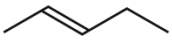
854. 9701_s19_qp_13 Q: 23

Which compound would produce a carboxylic acid and a ketone when treated with hot, concentrated acidified manganate(VII) ions?

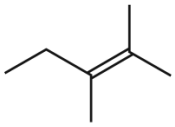
A



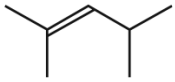
B



C



D



---

855. 9701_w19_qp_11 Q: 20

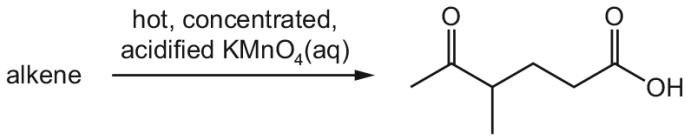
Which substance reacts with trichloroethene to give a chiral product?

A Br_2 **B** HC*l* **C** NaCN **D** NaOH

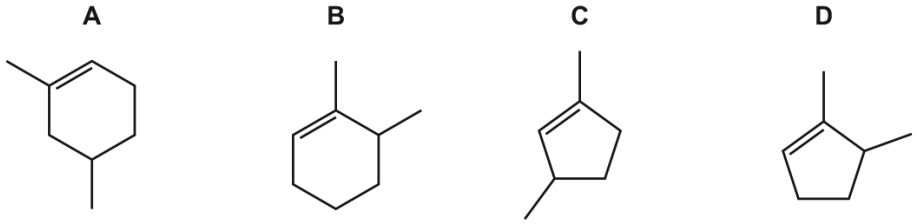
---

856. 9701_w19_qp_11 Q: 22

An alkene reacts with hot, concentrated, acidified potassium manganate(VII) to produce a single organic product as shown.



What is the structure of the alkene?



---

857. 9701_w19_qp_12 Q: 22

An organic compound X reacts with hot, concentrated acidified potassium manganate(VII) solution to give a single carbon-containing product.

What could be X?

A $CH_2C(CH_3)_2$

B $CH_3CHCHCH_3$

C $CH_2CHCH_2CH_3$

D $CH_3CH_2CH_2CH_3$

---

858. 9701_s18_qp_12 Q: 1

Which feature is present in both ethene and poly(ethene)?

A bond angles of 109°

B π covalent bonds

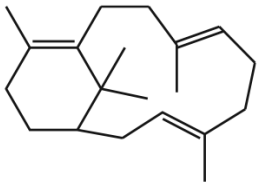
C σ covalent bonds

D sp^3 orbitals

---

859. 9701_s18_qp_12 Q: 20

Compound Y is treated with an excess of hydrogen gas in the presence of a nickel catalyst. The product is fully saturated.



compound Y

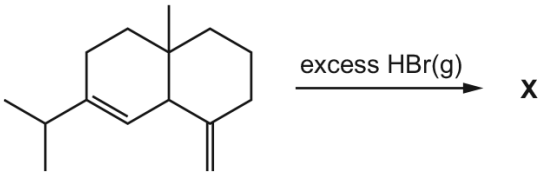
What is the number of chiral carbon atoms in the product?

A 5 **B** 6 **C** 7 **D** 8

---

860. 9701_s18_qp_13 Q: 21

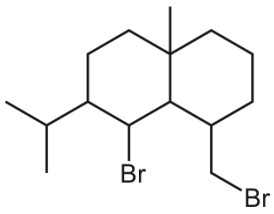
Sibirene, $C_{15}H_{24}$, is reacted with an excess of HBr(g). The major product is **X**.



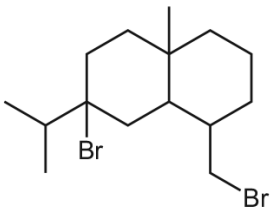
sibirene

What is the skeletal formula of **X**?

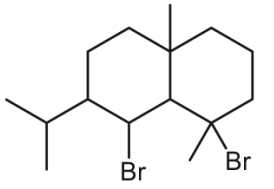
A



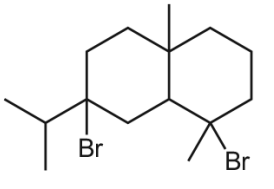
B



C



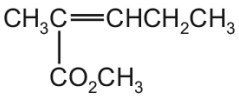
D



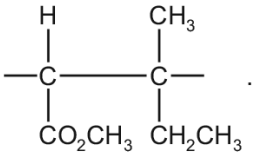
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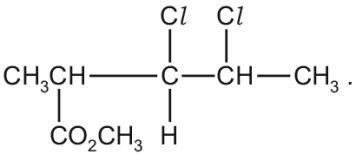
861. 9701_w18_qp_12 Q: 24

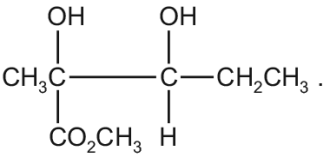
Which statement about compound Q is correct?

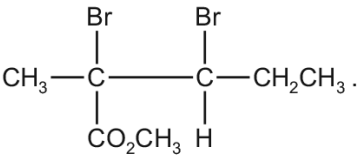


Q

A It could be polymerised to give a polymer with the repeat unit .

B It reacts with chlorine by a free radical mechanism to give .

C It reacts with cold, dilute acidified manganate(VII) to give .

D It reacts with bromine via a free radical mechanism to give .

---

862. 9701_m17_qp_12 Q: 23

Propene undergoes a variety of reactions.

Which row is correct?

	reagent added to propene	products include
A	$Br_2(aq)$	1-bromopropane
B	cold, dilute, acidified $KMnO_4(aq)$	propanoic acid
C	HBr(g)	2-bromopropane
D	hot, concentrated, acidified $KMnO_4(aq)$	propanoic acid

---

863. 9701_s17_qp_11 Q: 22

An alkene is reacted with acidified manganate(VII) ions, MnO_4^-. The desired organic product has a relative molecular mass greater than that of the alkene by 34.

What conditions should be used?

A cold, concentrated MnO_4^-

B cold, dilute MnO_4^-

C hot, concentrated MnO_4^-

D hot, dilute MnO_4^-

---

864. 9701_s17_qp_13 Q: 25

Bromine reacts with ethene in the dark.

Which description of the organic intermediate in this reaction is correct?

A It has a negative charge.

B It is a free radical.

C It is a nucleophile.

D It is an electrophile.

---

865. 9701_w17_qp_11 Q: 22

Many, but not all, organic reactions need to be heated before a reaction occurs.

Which reaction occurs quickly at room temperature, 20 °C?

A $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

B $C_2H_4 + H_2O \rightarrow CH_3CH_2OH$

C $CH_3CH_2OH \rightarrow C_2H_4 + H_2O$

D $CH_3CH_2OH + HBr \rightarrow CH_3CH_2Br + H_2O$

---

866. 9701_w17_qp_11 Q: 29

Ethene is reacted with steam in the presence of concentrated H_3PO_4. The product of this reaction is added to acidified potassium dichromate(VI) and heated under reflux for one hour. The final organic product is collected and labelled X.

But-2-ene is treated with hot, concentrated, acidified potassium manganate(VII). The final organic product is collected and labelled Y.

Which statement is correct?

A One molecule of X has more carbon atoms than one molecule of Y.

B One molecule of Y has more carbon atoms than one molecule of X.

C X and Y have different functional groups.

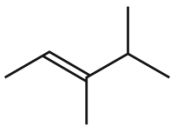
D X is the same compound as Y.

---

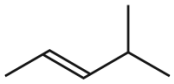
867. 9701_w17_qp_12 Q: 22

Which compound would produce two different carboxylic acids when treated with hot, concentrated, acidified manganate(VII) ions?

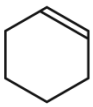
A



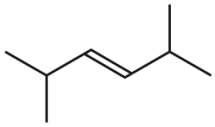
B



C



D



---

868. 9701_w17_qp_12 Q: 23

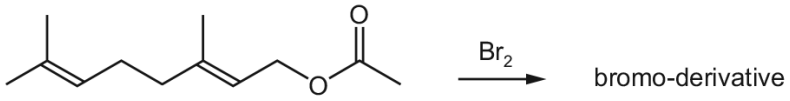
Which types of bond are broken and formed in the addition polymerisation of alkenes?

	type of bond broken	type of bond formed
A	π only	σ only
B	π only	σ and π
C	σ and π	σ only
D	σ and π	σ and π

---

869. 9701_s16_qp_11 Q: 30

Geranyl ethanoate is present in ginger and cocoa, and is used in shampoos and soaps as a perfume. It reacts with an excess of bromine in an organic solvent to give X, a bromo-derivative.



geranyl ethanoate X

Including geranyl ethanoate, how many cis-trans isomers are there of geranyl ethanoate, and how many chiral centres are there in X?

	cis-trans isomers	chiral centres in X
A	2	3
B	2	4
C	4	3
D	4	4

---

870. 9701_s16_qp_12 Q: 22

Oct-1-ene, $CH_3(CH_2)_5CH{=}CH_2$, can be thermally cracked.

Which combination of compounds W, X, Y and Z can be obtained by thermally cracking oct-1-ene?

$CH_2{=}CH_2$	$CH_3CH{=}CH_2$	$CH_3CH_2CH_3$	$CH_2{=}CHCH{=}CH_2$
W	X	Y	Z

A W, X, Y and Z

B W, X and Y only

C W, X and Z only

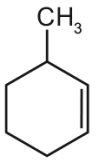
D W and X only

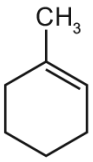
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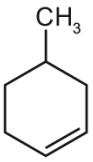
871. 9701_s16_qp_12 Q: 23

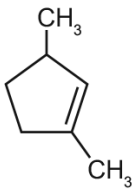
A cycloalkene with the molecular formula C_7H_{12} was oxidised by hot concentrated acidified MnO_4^-. The only organic product was 2-methylhexane-1,6-dioic acid.

What is the identity of the cycloalkene?

A 

B 

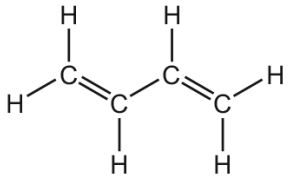
C 

D 

---

872. 9701_s16_qp_13 Q: 21

The diagram shows the structure of 1,3-butadiene.



1,3-butadiene

The addition reaction between 1,3-butadiene and two molecules of hydrogen bromide can produce three structurally isomeric products.

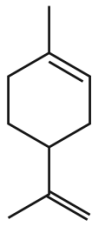
How many of these products have at least one chiral centre?

A 0 **B** 1 **C** 2 **D** 3

---

873. 9701_w16_qp_12 Q: 20

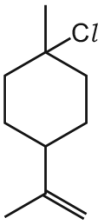
Limonene is found in lemon and orange oils.



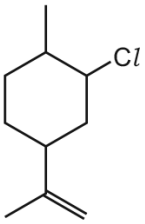
limonene

What will be the major product when limonene is reacted with an excess of dry hydrogen chloride?

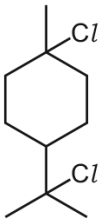
A



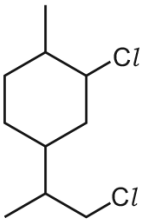
B



C



D



---

874. 9701_s15_qp_11 Q: 22

Cottonseed oil contains large amounts of polyunsaturated carboxylic acids. When this oil is used to make margarine, the C=C double bonds in the unsaturated carboxylic acids are hydrogenated.

What reagents and conditions would be suitable to bring about this hydrogenation reaction?

A H_2 gas, nickel catalyst, 400 °C

B $LiAlH_4$ in dry ether

C $NaBH_4$, aqueous solution

D steam, concentrated H_2SO_4, 300 °C and 60 atm pressure

---

875. 9701_s15_qp_11 Q: 23

Which intermediate ion forms in the greatest amount during the addition of HBr to propene?

A $CH_3CH^+CH_3$

B $CH_3CH_2CH_2^+$

C $CH_3CH^-CH_2Br$

D $CH_3CHBrCH_2^-$

---

876. 9701_s15_qp_12 Q: 22

Four students, W, X, Y and Z, made the following statements about alkanes and alkenes.

W 'Bromine reacts with alkanes by electrophilic substitution.'

X 'Bromine reacts with alkenes by a free-radical addition mechanism.'

Y 'Alkenes can be oxidised by acidified manganate(VII) ions.'

Z 'Alkenes are formed from alkanes by cracking.'

Which two students are correct?

A W and X **B** W and Z **C** X and Y **D** Y and Z

Chapter 14

Hydrocarbons

14.1 Alkanes

99. 9701_m21_qp_22 Q: 2

Chlorine, Cl_2, is a reactive yellow-green gas. It is a strong oxidising agent.

(a) State how Cl_2 is used in water purification.

.....

..... [1]

(b) Chlorine has the highest first ionisation energy of the Period 3 elements Na to Cl.

(i) Construct an equation for the first ionisation energy of chlorine.

Include state symbols.

..... [1]

(ii) Explain the general increase in the first ionisation energies of the Period 3 elements.

.....

.....

.....

..... [2]

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(c) The halide ions, X^- (where X = C*l*, Br, I), show clear trends in their physical and chemical properties.

(i) State and explain the relative thermal stabilities of the hydrogen halides, HX.

.....

.....

..... [2]

The halide ions react easily with concentrated H_2SO_4.

The main sulfur-containing product of each reaction is shown in the table.

halide ion	C*l*$^-$	Br$^-$	I$^-$
main sulfur-containing product of reaction with concentrated H_2SO_4	HSO_4^-	SO_2	H_2S
oxidation number of sulfur			

(ii) Complete the table to show the oxidation number of sulfur in each of the sulfur-containing products. [1]

(iii) Explain why different sulfur-containing products are produced when each of these halide ions reacts with concentrated H_2SO_4.

.....

..... [1]

(d) Cl_2 reacts with aqueous sodium hydroxide in a disproportionation reaction.

(i) State what is meant by *disproportionation*.

.....

..... [1]

(ii) Write an equation for the reaction of Cl_2 with cold aqueous sodium hydroxide.

..... [1]

(e) Aluminium reacts with chlorine to form aluminium chloride.

Aluminium chloride can exist as the gaseous molecule Al_2Cl_6(g). This molecule contains coordinate bonds.

(i) Draw a diagram that clearly shows all the types of bond present in Al_2Cl_6(g).

[2]

(ii) Describe what you would see when solid aluminium chloride reacts with water.

Name the type of reaction that occurs.

.....

.....

..... [2]

(f) 0.020 mol of element **Z** reacts with excess Cl_2 to form 0.020 mol of a liquid chloride.

The liquid chloride has formula **Z**Cl_n, where *n* is an integer.

ZCl_n reacts vigorously with water at room temperature to give an acidic solution and a white solid.

When excess $AgNO_3$(aq) is added to the solution, 11.54 g of AgCl(s) forms.

(i) Suggest the type of bonding and structure shown by **Z**Cl_n.

..... [1]

(ii) Calculate the value of *n* in **Z**Cl_n.

n = ... [2]

(g) Dichloromethane, CH_2Cl_2, is widely used as an organic solvent.

CH_2Cl_2 can be prepared by reacting CH_3Cl and Cl_2 at room temperature.

The reaction proceeds via several steps, as shown.

$$Cl_2 \xrightarrow{\text{initiation}} 2Cl^{\bullet}$$

$$Cl^{\bullet} + CH_3Cl \xrightarrow{\text{propagation 1}} HCl + {}^{\bullet}CH_2Cl$$

$$Cl_2 + {}^{\bullet}CH_2Cl \xrightarrow{\text{propagation 2}} \text{products}$$

$$Cl^{\bullet} + {}^{\bullet}CH_2Cl \xrightarrow{\text{final step}} CH_2Cl_2$$

(i) Give the name of the mechanism of this reaction.

..... [1]

(ii) State the essential condition required for the initiation step to take place.

..... [1]

(iii) Give the electronic configuration of $Cl^{\bullet}$.

$1s^2$ ..... [1]

(iv) Identify the products of the step labelled propagation 2.

..... [1]

(v) Name the type of reaction shown in the final step.

..... [1]

(vi) Suggest the identity of another organic molecule that is a product of the reaction of CH_3Cl and Cl_2 under the same conditions.

..... [1]

[Total: 23]

100. 9701_w19_qp_21 Q: 1

(a) Chlorine can be prepared using the following reaction.

$$MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

(i) Explain why $MnO_2(s)$ is described as an oxidising agent in this reaction.

Refer to oxidation numbers in your answer.

.....

..... [1]

(ii) State what you would observe during this reaction.

..... [1]

(b) The halogens chlorine, bromine and iodine are all volatile elements.

State and explain the trend in volatility down Group 17.

.....

.....

..... [3]

(c) Chlorine undergoes disproportionation during many chemical reactions.

(i) Write an equation for the reaction of chlorine with cold aqueous sodium hydroxide, NaOH.

Explain why it is a disproportionation reaction.

equation .....

explanation .....

.....
[2]

(ii) One of the products of the reaction of chlorine with **hot** aqueous sodium hydroxide differs from those in **(c)(i)**.

Identify the compound that is formed in this reaction that is different from that formed in the reaction in **(c)(i)**.

..... [1]

(d) State and explain the use of chlorine in water purification.

.....

.....

..... [2]

(e) Under certain conditions, chlorine undergoes a free-radical substitution reaction with ethane.

(i) State the conditions required to initiate this reaction.

..... [1]

(ii) Write the overall equation for this free-radical substitution reaction.

..... [1]

[Total: 12]

---

101. 9701_w19_qp_21 Q: 3

Crude oil is a natural source of hydrocarbons that are used as fuels.

(a) Hydrocarbons with low relative molecular mass, M_r, are used as fuels in industry, in the home and for transport.

There is a high demand for the hydrocarbons with low M_r.

(i) Name the process by which long-chain hydrocarbons are broken down into shorter-chain hydrocarbons.

..... [1]

(ii) Give one reason why hydrocarbons with low M_r are suitable for use as fuels.

..... [1]

(iii) Incomplete combustion of hydrocarbons can release carbon monoxide, CO, into the atmosphere.

Write an equation for the formation of CO from the incomplete combustion of butene, C_4H_8.

..... [1]

(iv) Identify an analytical technique that can be used to monitor the levels of CO in the atmosphere.

Outline how this analytical technique may be used to monitor the levels of CO.

.....

.....

..... [2]

(b) Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

(i) Construct the equation for the complete combustion of thiophene, $C_4H_4S(l)$.

Include state symbols in your answer.

..... [2]

(ii) A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

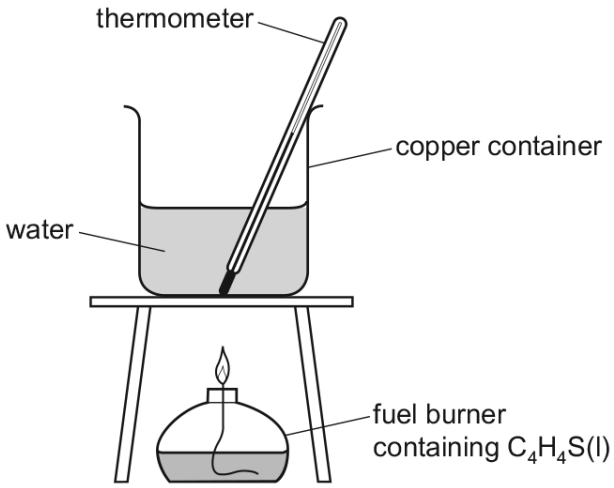
Explain the meaning of the term *enthalpy change of combustion*.

.....

.....

..... [2]

(iii) The student uses the following apparatus in the experiment.



mass of water in copper container / g	200
initial temperature of water / °C	18.5
highest temperature of water / °C	37.5

Calculate the heat energy released, in J, by the reaction.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of water by 1.0 °C.

Assume no heat is lost to the surroundings.

heat energy released = ... J
[2]

(iv) The student used 0.63 g of $C_4H_4S(l)$ in the experiment.

Calculate the enthalpy change of combustion of thiophene, $\Delta H_c(C_4H_4S(l))$. Include a sign in your answer.

$\Delta H_c(C_4H_4S(l))$ = ... $kJ\,mol^{-1}$
[2]

[Total: 13]

102. 9701_m18_qp_22 Q: 2

Carbon and silicon are elements in Group 14.

(a) C_{60} and diamond are allotropes of carbon.

(i) Describe the lattice structure of solid C_{60}.

.....

.....

.....

..... [2]

(ii) C_{60} sublimes (turns directly from solid to gas) at about 800 K. Diamond also sublimes but only above 3800 K.

Explain why C_{60} and diamond sublime at such different temperatures.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(b) C_{60} forms hydrocarbons with similar chemical properties to those of alkenes. One such hydrocarbon is $C_{60}H_{18}$.

(i) State what is meant by the term *hydrocarbon*.

.....

..... [1]

(ii) Describe a test to indicate the presence of double bonds between carbon atoms in $C_{60}H_{18}$. Give the result of the test.

test .....

.....

result .....

.....

[2]

(c) 0.144 g of C_{60} was placed in a 100 cm^3 container of hydrogen gas at 20 °C and 1.00×10^5 Pa.

The container was heated to make the C_{60} and hydrogen gas react.

The reaction occurred as shown in the equation.

$$C_{60}(s) + xH_2(g) \rightarrow C_{60}H_{2x}(s)$$

After the reaction, the container was allowed to cool to 20 °C. The pressure decreased to 2.21×10^4 Pa. All of the C_{60} had reacted.

(i) Name the type of reaction that occurred.

..... [1]

(ii) Calculate the amount, in moles, of C_{60} that reacted.

amount of C_{60} = ... mol [1]

(iii) Calculate the amount, in moles, of hydrogen gas that reacted with the C_{60}.

amount of hydrogen gas = ... mol [2]

(iv) Use your answers from **(ii)** and **(iii)** to deduce the molecular formula of the hydrocarbon, $C_{60}H_{2x}$.

If you were unable to calculate the amount of hydrogen gas, assume that 0.00240 mol of hydrogen gas reacted. This is **not** the correct value for the amount of hydrogen gas that reacted.

molecular formula = ... [2]

STEMUP.CO.UK

(d) Silicon shows the same kind of bonding and structure as diamond.

(i) State the type of bonding and structure shown by silicon.

.....

.....

..... [2]

(ii) When silicon reacts with magnesium, Mg_2Si forms. Mg_2Si is thought to contain the Si^{4-} ion.

State the full electronic configuration of the Si^{4-} ion.

$1s^2$..... [1]

(iii) Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

Write an equation to show the reaction of solid Mg_2Si with dilute hydrochloric acid.

Include state symbols.

..... [2]

(iv) Predict the shape of the SiH_4 molecule.

..... [1]

(v) SiH_4 reacts spontaneously with oxygen to produce a white solid and a colourless liquid that turns anhydrous copper(II) sulfate blue. No other products are formed.

Write an equation for the reaction of SiH_4 with oxygen.

State symbols are **not** required.

..... [1]

[Total: 22]

103. 9701_s18_qp_21 Q: 2

Crude oil is a complex mixture of hydrocarbon molecules.

The hydrocarbon molecules in crude oil are separated by fractional distillation. Fractional distillation is used because the different hydrocarbon molecules in crude oil have different boiling points.

(a) Explain why the hydrocarbon molecules in crude oil have different boiling points.

.....

.....

.....

.....

.....

.....

..... [2]

(b) Some of the hydrocarbon molecules obtained from crude oil are processed further by cracking.

Suggest why some hydrocarbon molecules are processed further by cracking.

.....

.....

..... [1]

(c) Cracking one mole of dodecane, $C_{12}H_{26}$, produces two moles of ethene and one mole of another hydrocarbon molecule.

(i) Write the equation for this cracking reaction.

..... [1]

The ethene can be used in the production of poly(ethene).

(ii) Give the full name of the process used to produce poly(ethene) from ethene.

..... [1]

(iii) Give **two** reasons why poly(ethene) should be reused or recycled rather than just thrown away.

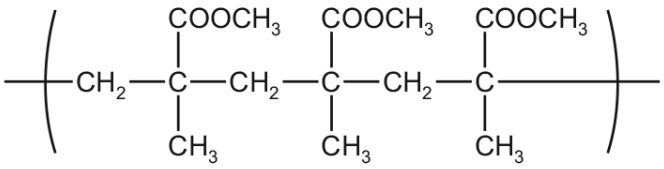
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.....

.....

..... [2]

(iv) Part of a polymer chain, produced by the same type of process as poly(ethene), is shown.



Give the **displayed** formula of the monomer used to produce this polymer.

[2]

[Total: 9]

104. 9701_s18_qp_22 Q: 3

Most vehicle fuels contain hydrocarbons obtained from crude oil.

(a) (i) State the name of the type of reaction that hydrocarbons undergo when being used as fuels.

..... [1]

(ii) Write an equation for the reaction of octane, C_8H_{18}, as a fuel, as in **(a)(i)**.

..... [2]

(b) The supply of material suitable for use as fuels directly from crude oil is **not** sufficient to meet demand. A process is carried out to make some of the larger hydrocarbon molecules more useful.

(i) Name this process.

..... [1]

As well as producing fuels, this process produces compounds suitable for use in the production of polymers. An example of such a compound is but-2-ene, $CH_3CH{=}CHCH_3$.

(ii) Draw the repeat unit of the polymer that is produced from but-2-ene.

[2]

(iii) Name the type of polymerisation that occurs during the production of the polymer in **(ii)**.

..... [1]

(c) Gases produced in internal combustion engines include carbon monoxide, oxides of nitrogen such as NO_2, and unburnt hydrocarbons.

These gases are removed from the exhaust before they can enter the atmosphere.

(i) State what is used to remove these gases from the exhaust.

..... [1]

(ii) Write **one** equation to show how both carbon monoxide, CO, and nitrogen dioxide, NO_2, are removed from the exhaust.

..... [1]

(iii) State the environmental consequence of allowing unburnt hydrocarbons to enter the atmosphere.

..... [1]

(d) Vehicle fuels are treated to remove sulfur. If sulfur is present in a fuel when it is burned, SO_2 is produced and may be released into the atmosphere where it can form acid rain.

(i) Acid rain can contribute to breathing difficulties.

Identify **two** other consequences of acid rain in the atmosphere.

.....

.....

.....

..... [2]

(ii) NO_2 is involved in the production of acid rain from SO_2.

Give **two** equations which describe how acid rain is formed by the action of NO_2 with SO_2.

.....

..... [2]

(iii) NO_2 is described as a catalyst during this process.

Explain, with the use of an appropriate equation, why NO_2 is described as a catalyst.

.....

..... [2]

[Total: 16]

105. 9701_s17_qp_23 Q: 1

Combustion data can be used to calculate the empirical formula, molecular formula and relative molecular mass of many organic compounds. Combustion data cannot distinguish between different structural isomers.

(a) Define the term *structural isomers*.

.....

.....

.....

..... [2]

(b) **P** is a hydrocarbon, C_xH_y. A gaseous sample of **P** occupied a volume of 25 cm^3 at 37 °C and 100 kPa.

The sample was completely burned in 200 cm^3 of oxygen (an excess).
The final volume, measured under the same conditions as the gaseous sample (so that the water produced is liquid and its volume can be ignored), was 150 cm^3.

Treating the remaining gaseous mixture with concentrated alkali, to absorb carbon dioxide, decreased the volume to 50 cm^3.

The equation for the complete combustion of **P** can be represented as shown.

$$C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

(i) Use the data given to calculate the value of x.

x = ... [1]

(ii) Use the data given to calculate the value of $(x + \frac{y}{4})$.

$(x + \frac{y}{4})$ = ... [1]

If you were unable to calculate values in **(b)(i)** and **(b)(ii)** then use the data in this box for the remaining parts of this question. These are **not** the correct values.

$x = 6$ $\left(x + \frac{y}{4}\right) = 9$

(iii) Give the molecular formula and the empirical formula of **P**.

molecular formula of **P** .....

empirical formula of **P** .....

[2]

(iv) **P** is unbranched.

Give the skeletal formulae for two possible structures of **P** that are positional isomers of each other.

[2]

(v) Use the general gas equation to calculate the mass of **P** present in the original 25 cm^3 gaseous sample, which was measured at 37 °C and 100 kPa.

Give your answer to **three** significant figures.

mass = ... g [3]

[Total: 11]

106. 9701_w15_qp_21 Q: 3

Heptane, C_7H_{16}, is an undesirable component of petrol as it burns explosively causing 'knocking' in an engine.

(a) There are nine structural isomers with the formula C_7H_{16}, only two of which contain chiral centres.

(i) Explain the meanings of the terms *structural isomers* and *chiral*.

structural isomers .....

.....

.....

chiral .....

.....

.....

[2]

(ii) Give the structures and names of the two structural isomers of C_7H_{16} which contain a chiral centre.

[4]

(b) **(i)** Write an equation for the complete combustion of heptane.

..... [1]

(ii) Write an equation for the incomplete combustion of heptane leading to the production of a solid pollutant.

..... [1]

(iii) Incomplete combustion can also lead to emission of unburnt hydrocarbons.

State one environmental consequence of this.

..... [1]

(c) The reaction of heptane with chlorine in the presence of UV light produces a wide variety of products.

Formation of the monochloroheptanes can be represented by the following equation.

$$C_7H_{16} + Cl_2 \rightarrow C_7H_{15}Cl + HCl$$

(i) Name the mechanism of the reaction between heptane and chlorine in the presence of UV light.

..... [1]

(ii) Describe this mechanism, using suitable equations and including the names of each stage in the process.

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

[Total: 15]

14.2 Alkenes

107. 9701_s21_qp_21 Q: 5

(a) Naphtha is a mixture which contains only hydrocarbon molecules.

(i) What is meant by the term *hydrocarbon*?

.....

..... [1]

(ii) Name the raw material that is used to produce a sample of naphtha.

..... [1]

(b) Compound **V** is found in naphtha. It has a molecular formula $C_{10}H_{22}$.

When **V** is heated at high pressure in the absence of air, an equal number of moles of ethene, propene and **W** are made. **W** is a compound made of straight chain, saturated molecules.

(i) Name the process that describes this reaction.

..... [1]

(ii) Deduce the structure of **W**. Draw its structure below.

[1]

(c) Propene is separated from the mixture and heated in air in the presence of a catalyst. Propene is oxidised to **X**, which contains two functional groups.

(i) Effervescence is seen when $Na_2CO_3(aq)$ is added to **X**.

Identify the functional group present in **X** which is responsible for this observation.

..... [1]

(ii) Identify a reagent which could be used to show that **X** contains a C=C. Include relevant observations.

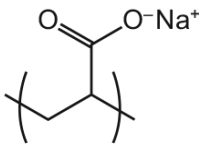
.....

..... [2]

(d) **X** reacts with another reagent to form **Y**.

Molecules of **Y** react together to form addition polymer **Z**. The diagram shows the repeat unit of polymer **Z**.

repeat unit of polymer **Z**



Draw the structural formula of monomer **Y**.

[1]

(e) Polymer **Z** is useful because it absorbs large amounts of water. However, there are problems associated with the disposal of products containing polymer **Z**.

Combustion is not an appropriate method to dispose of pure **Z** because the process releases harmful gases. Some of these gases contribute to the enhanced greenhouse effect.

(i) Identify a gas released during the combustion of **Z** which contributes to the enhanced greenhouse effect.

..... [1]

(ii) Identify another gas which could be produced during the combustion of pure **Z**. Describe a consequence, other than the enhanced greenhouse effect, of its release into the atmosphere.

gas .....

consequence .....
[1]

[Total: 10]

108. 9701_w21_qp_22 Q: 1

Hydrogen iodide, HI, is a colourless gas at room temperature.

(a) (i) Explain why HI has a higher boiling point than HC*l* and HBr.

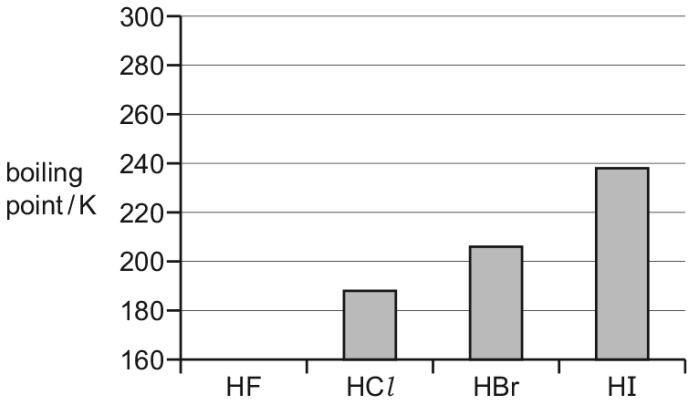
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.....

.....

..... [2]

(ii) The bar chart shows the boiling points of HC*l*, HBr and HI. The boiling point of HF is not shown.



Hydrogen bonds form between HF molecules.

Draw a bar on the bar chart to predict the boiling point of HF.

Explain your answer.

.....

..... [2]

(b) The standard enthalpy change of formation, $\Delta H_f^\ominus$, of HI(g) is +26.5 kJ mol^{-1}.

Define the term *standard enthalpy change of formation*.

.....

.....

..... [2]

(c) HI(g) can be formed by reacting $H_2(g)$ with $I_2(g)$. The reaction is reversible, and an equilibrium forms quickly at high temperatures.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(i) Construct an expression for the equilibrium constant, K_p, for the reaction of $H_2(g)$ and $I_2(g)$ to form HI(g).

K_p =

[1]

(ii) The equilibrium partial pressures of the gases at 200 °C are as follows.

$$p_{H_2(g)} = 895\,Pa$$
$$p_{I_2(g)} = 895\,Pa$$
$$p_{HI(g)} = 4800\,Pa$$

Calculate K_p for this reaction.

K_p = ... [1]

(iii) State how the value of K_p would change, if at all, if the reaction were carried out at 100 °C rather than 200 °C.

Explain your answer.

.....

.....

.....

..... [2]

(d) HI reacts with oxygen to form iodine and water.

(i) Construct an equation for the reaction of HI with oxygen.

..... [1]

(ii) Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

.....

.....

.....

..... [2]

(e) HI(g) can also be formed by the reaction of $I_2(g)$ with hydrazine, $N_2H_4(g)$.

$$2I_2(g) + N_2H_4(g) \rightarrow 4HI(g) + N_2(g)$$

State the change in pressure that would occur when 2 mol $I_2(g)$ fully reacts with 1 mol $N_2H_4(g)$ in a sealed container at constant temperature. Explain your answer.

.....

.....

.....

..... [2]

(f) In the laboratory, HI(aq) can be formed in a two-step process.

step 1 $3I_2(s) + 2P(s) \rightarrow 2PI_3(s)$

step 2 $PI_3(s) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HI(aq)$

(i) Draw a 'dot-and-cross' diagram of a PI_3 molecule.

[2]

(ii) Name the type of reaction in **step 2**.

..... [1]

(iii) $H_3PO_3(aq)$ and HI(aq) are both strong Brønsted–Lowry acids.

Give the meaning of the term *strong Brønsted–Lowry acid*.

.....

.....

..... [2]

(iv) Give the formula of the conjugate base of H_3PO_3.

..... [1]

(g) HI(g) reacts with propene, $CH_3CH{=}CH_2(g)$ to form a mixture of 1-iodopropane and 2-iodopropane.

(i) Identify which of 1-iodopropane and 2-iodopropane is the major product of this reaction.

Explain your answer.

.....

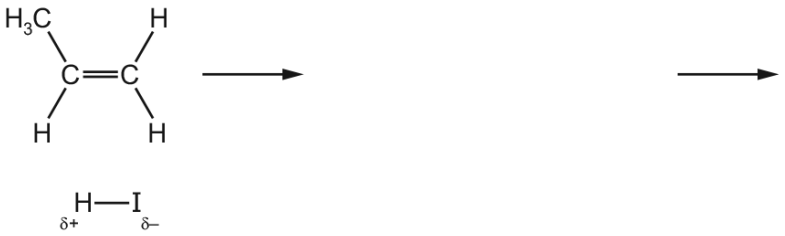
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.....

..... [2]

(ii) Complete the diagram to show the mechanism of the reaction between HI and $CH_3CH{=}CH_2$ that forms the major product identified in **(g)(i)**.

Include curly arrows, lone pairs of electrons and charges as necessary.



[3]

[Total: 26]

109. 9701_s20_qp_23 Q: 4

Hexane, C_6H_{14}, is a colourless liquid.
Two test-tubes contain equal amounts of hexane. 1 cm^3 of bromine, $Br_2(aq)$, is added to both test-tubes. One test-tube is kept in the dark and the other is exposed to sunlight.

The table describes the appearance of each test-tube after one hour.

test-tube conditions	observations
in the dark	no change, mixture remains orange
in sunlight	colour of mixture fades to pale yellow

(a) The test-tube in the dark is kept cool and is not exposed to ultraviolet light.

Explain the observations for the test-tube kept in the dark.

.....

..... [2]

(b) In sunlight, bromine reacts with hexane by a mechanism which occurs via a series of steps.

(i) State the name of the mechanism of the reaction that occurs.

..... [1]

(ii) Give an equation which shows a propagation step in this reaction in which hexane produces $\bullet C_6H_{13}$.

..... [1]

(iii) Give an equation which shows a propagation step in this reaction that produces 1-bromohexane.

..... [1]

(iv) Give an equation which shows a termination step in this reaction that produces 1-bromohexane.

..... [1]

(c) **A** and **B** are different straight chain alkenes with molecular formula, C_6H_{12}.

A does not show stereoisomerism.

A reacts with potassium manganate(VII) to form hexane-1,2-diol.

(i) Draw the structural formula of **A**.

[1]

(ii) State the conditions needed for this reaction of **A**.

..... [2]

(d) **B** reacts with hydrogen gas in the presence of a platinum catalyst to produce hexane.

(i) Name the type of reaction occurring.

..... [1]

(ii) In terms of σ and π bonds, describe any similarities and differences in the type of carbon-carbon bonds in **B** and the type of carbon-carbon bonds in hexane.

.....

.....

..... [2]

[Total: 12]

110. 9701_w20_qp_21 Q: 4

Iodine is used in many inorganic and organic reactions.

(a) (i) State and explain the trend in volatility of the halogens, from chlorine to iodine.

.....

.....

.....

..... [2]

(ii) Explain why HI is the **least** thermally stable of HC*l*, HBr and HI.

.....

..... [1]

(iii) The table shows the electronegativity values for hydrogen, fluorine and iodine.

element	electronegativity value
H	2.1
F	4.0
I	2.5

Explain, in terms of intermolecular forces, why HI has a lower boiling point than HF.

.....

.....

.....

..... [2]

(iv) Iodine reacts with hot concentrated aqueous sodium hydroxide in the same way as chlorine.

Write an equation for the reaction of iodine and hot aqueous sodium hydroxide.

..... [1]

(b) Iodoalkanes contain carbon-iodine bonds.

The simplest iodoalkane is CH_3I.

(i) CH_3I can be made from methanol, CH_3OH.

Identify a reagent that can convert CH_3OH to CH_3I.

..... [1]

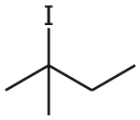
(ii) 1,2-diiodoethane, CH_2ICH_2I, can be made by bubbling ethene into liquid iodine.

Fully name the type of mechanism shown in this reaction.

..... [1]

(c) **J** reacts with NaOH, forming different products dependent on the conditions used.

J

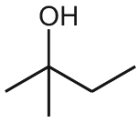


(i) Name **J**.

..... [1]

(ii) **J** reacts with NaOH(aq) to form **K**.

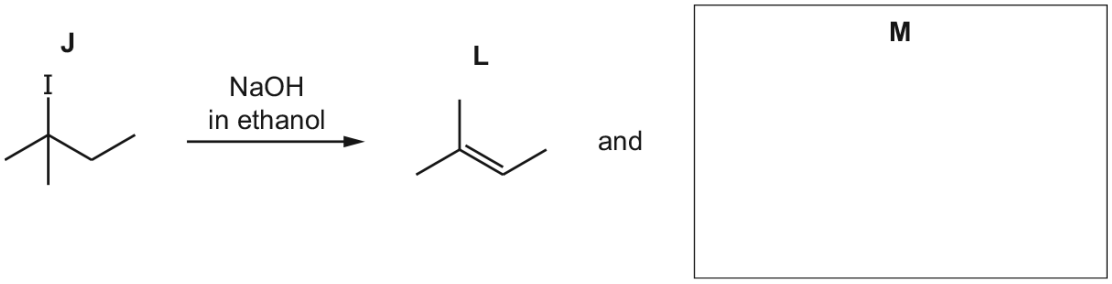
K



Fully name the mechanism of the reaction of **J** with NaOH(aq) to form **K**.

..... [1]

(iii) **J** reacts with NaOH dissolved in ethanol to form a mixture of two alkenes, **L** and **M**. Alkene **L** is shown.



In the box provided, draw the structure of **M**. [1]

(iv) Explain why **L** does **not** show geometrical (cis-trans) isomerism.

.....

.....

..... [1]

(v) **L** reacts with hot concentrated acidified $KMnO_4(aq)$ to form propanone and one other organic product.

Identify the other organic product.

..... [1]

(vi) Propanone reacts with excess alkaline aqueous iodine.

Complete and balance the equation for this reaction.

CH_3COCH_3 + ...I_2 + ...OH^- ⟶ .....CH_3COO^- + ...H_2O + ...I^- + ...
[2]

(vii) State **one** observation that can be made in the reaction in **(c)(vi)**.

..... [1]

[Total: 16]

111. 9701_m19_qp_22 Q: 1

Nitrogen, N_2, is the most abundant gas in the Earth's atmosphere and is very unreactive.

(a) State why N_2 is very unreactive.

..... [1]

(b) Magnesium and lithium both form nitrides with N_2. These compounds both contain the N^{3-} ion.

(i) Write an equation for the reaction of magnesium with N_2 to form magnesium nitride.

..... [1]

(ii) Solid lithium nitride, Li_3N, reacts with water according to the following equation.

$$Li_3N(s) + 3H_2O(l) \rightarrow 3LiOH(aq) + NH_3(aq)$$

State **one** observation you would make during this reaction.

..... [1]

(c) (i) State the industrial importance of ammonia.

..... [1]

(ii) One method of producing NH_3 is by heating ammonium chloride, NH_4Cl, with CaO.

$$2NH_4Cl + CaO \rightarrow 2NH_3 + CaCl_2 + H_2O$$

Explain why the reaction of NH_4Cl with CaO produces ammonia.

.....

.....

..... [2]

(d) Three oxides of nitrogen, NO, NO_2 and N_2O, can be formed under different conditions.

(i) Complete the table to give the oxidation numbers of nitrogen in NO and NO_2.

compound	NO	NO_2
oxidation number of N		

[1]

(ii) NO_2 can be formed by different chemical reactions.

Write equations for the formation of NO_2 by:

- the reaction of N_2 with O_2

.....

- the thermal decomposition of magnesium nitrate.

.....

[2]

(iii) Molecules of N_2O can be formed by the reaction between N_2 and O_2. The bond between the N and O atoms (N→O) is a co-ordinate (dative covalent) bond.

$$2N_2(g) + O_2(g) \rightarrow 2N{\equiv}N{\rightarrow}O(g)$$

The enthalpy change of reaction for this reaction is +82 kJ mol^{-1}.

Calculate the bond enthalpy, in kJ mol^{-1}, of the N→O bond.

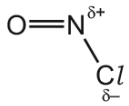
Use relevant data from the *Data Booklet* to answer this question.

bond enthalpy of the N→O bond = ... kJ mol^{-1}

[2]

(e) Nitrosyl chloride, NOCl, is a reactive gas that is sometimes formed when NO reacts with Cl_2.

nitrosyl chloride



NOCl is a strong electrophile and readily undergoes an addition reaction with alkenes.

Complete the diagram to show the mechanism of the electrophilic addition reaction of NOCl with ethene.

Include all necessary charges, lone pairs and curly arrows, and the structure of the organic intermediate.



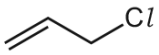
[2]

[Total: 13]

112. 9701_m19_qp_22 Q: 4

Allyl chloride is an important chemical used in the manufacture of plastics, pharmaceuticals and pesticides.

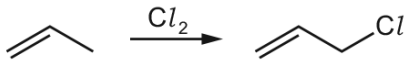
allyl chloride



(a) Give the systematic name of allyl chloride.

..... [1]

(b) Allyl chloride can be produced by many different methods. The most common method is chlorination of propene which proceeds via a free-radical substitution mechanism.



(i) The initiation step in this reaction is the formation of chlorine radicals ($Cl^{\bullet}$) from Cl_2 molecules.

State the conditions required to initiate this reaction.

..... [1]

(ii) The propenyl radical, $CH_2{=}CHCH_2^{\bullet}$, is formed in the first propagation step of the reaction.

Write an equation to show the formation of $CH_2{=}CHCH_2^{\bullet}$ in this propagation step.

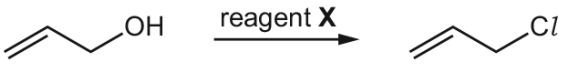
..... [1]

(iii) Explain why the free-radical substitution reaction gives a low yield of allyl chloride.

.....

..... [1]

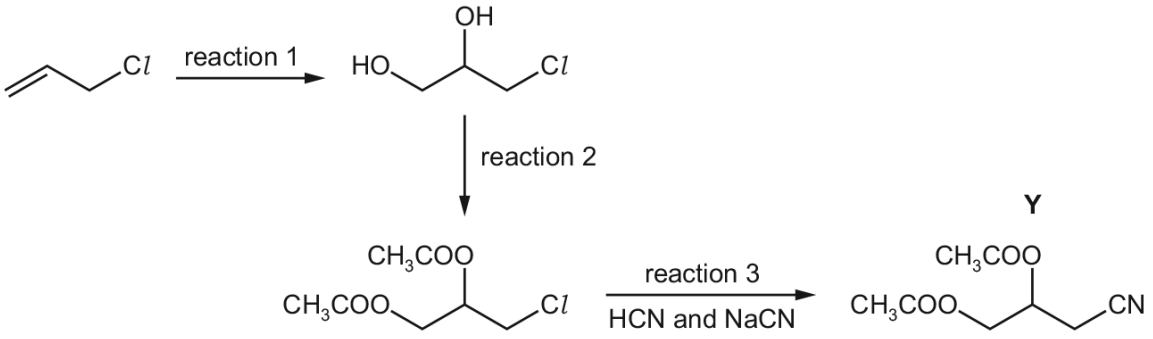
(iv) Allyl chloride can also be formed by the following substitution reaction.



Suggest the identity of reagent **X**.

..... [1]

(c) A series of reactions starting from allyl chloride is shown.



(i) Suggest a reagent that can be used in reaction 1.

..... [1]

(ii) In reaction 2, the organic product of reaction 1 is mixed with concentrated H_2SO_4 and an organic acid, and then heated under reflux.

State the role of the concentrated H_2SO_4. Identify the organic acid used.

role of the concentrated H_2SO_4 .....

identity of the organic acid .....

[2]

(iii) State the name of the mechanism that occurs in reaction 3.

..... [1]

(iv) The organic product of reaction 3 is **Y**.

Y can be hydrolysed using excess aqueous H_2SO_4 to form **Z**.

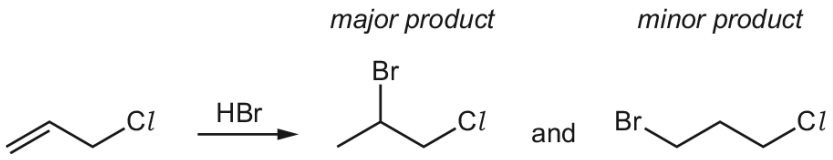
The molecular formula of **Z** is $C_4H_8O_4$.

Draw the structure of **Z**.

[2]

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(d) 2-bromo-1-chloropropane, $CH_3CHBrCH_2Cl$, is the major product of the reaction of allyl chloride with HBr.



Explain why 2-bromo-1-chloropropane is the major product of this reaction.

.....

.....

.....

..... [2]

[Total: 13]

113. 9701_s19_qp_22 Q: 4

There are many different types of aliphatic and aromatic hydrocarbons.

(a) Name a naturally occurring source of aliphatic and aromatic hydrocarbons and outline how different hydrocarbons are separated from this source.

name of source .....

outline of separation of hydrocarbons .....

.....

[2]

(b) When alkanes are heated to high temperatures, in the absence of air, the molecules can break into smaller molecules.

(i) Identify the type of reaction occurring.

..... [1]

(ii) Write an equation which describes the reaction occurring when heptane, C_7H_{16}, is heated in the absence of air, to form hexane, butane and ethene only.

..... [1]

(c) The equation for the complete combustion of ethene is shown.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

Calculate the volume, in dm^3, of carbon dioxide formed in the complete combustion of 1.00 g of ethene at room temperature and pressure.

volume of CO_2 = ... dm^3 [3]

(d) The table compares the reactivity of alkanes and alkenes with chlorine.

	alkanes	alkenes
name of the type of reaction with chlorine	substitution	addition and substitution
name of the type of reacting species	free radical	electrophile and free radical

(i) During the first stage in the substitution reaction chlorine forms chlorine free radicals.

Explain what is meant by the term *free radical*.

..... [1]

(ii) Name and explain the type of bond breaking which occurs to form chlorine free radicals.

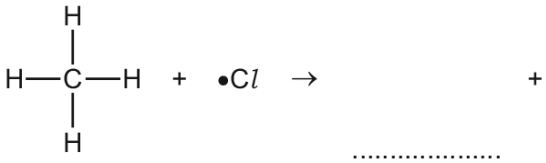
.....

..... [2]

(iii) Name the stage of the reaction mechanism which occurs when a methane molecule reacts with a chlorine free radical.

..... [1]

(iv) Complete the equation for the reaction which occurs when a methane molecule reacts with a chlorine free radical.



[1]

(v) Carbon atoms can form σ and π bonds within hydrocarbon molecules.

Explain the following statement with reference to σ and π bonds.

Alkenes react with electrophiles but alkanes do not.

.....

.....

.....

..... [2]

[Total: 14]

114. 9701_S15_qp_22 Q: 3

Ethane reacts with chlorine to form chloroethane.

$$C_2H_6(g) + Cl_2(g) \rightarrow C_2H_5Cl(g) + HCl(g)$$

(a) (i) Use bond energies from the *Data Booklet* to calculate the enthalpy change for this reaction. Include a sign in your answer.

enthalpy change = ... $kJ\,mol^{-1}$ [3]

(ii) State the conditions needed for this reaction to occur.

..... [1]

(iii) Use a series of equations to describe the mechanism of this reaction including the names of each stage and an indication of how butane can be produced as a minor by-product.

.....

.....

.....

.....

.....

..... [5]

(b) Chloroethane can be converted back into ethane by a two-stage process via an intermediate compound, **X**.

$$C_2H_5Cl \xrightarrow{\text{reaction 1}} \mathbf{X} \xrightarrow{\text{reaction 2}} C_2H_6$$

(i) Give the name of **X**.

..... [1]

(ii) Suggest the reagent and conditions needed for reaction 1.

..... [2]

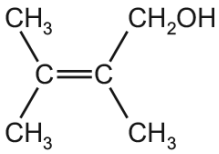
(iii) Suggest the reagent and conditions needed for reaction 2.

..... [1]

[Total: 13]

115. 9701_S15_qp_23 Q: 4

The structure of **H** is shown.



H

(a) **H** reacts with both cold, dilute, acidified potassium manganate(VII) and with hot, concentrated, acidified potassium manganate(VII).

(i) Give the structure of the organic product of the reaction of **H** with cold, dilute, acidified potassium manganate(VII).

[1]

(ii) Give the structures of the organic products of the reaction of **H** with hot, concentrated, acidified potassium manganate(VII).

[2]

(b) **(i)** Complete the reaction scheme to show the mechanism of the reaction of **H** with bromine to form **J**.

Include all necessary curly arrows, lone pairs and charges.



J

[3]

(ii) Explain the origin of the dipole on the bromine molecule.

.....

..... [1]

J is formed as an equimolar mixture of isomers.

(iii) State the type of isomerism shown by **J**.

..... [1]

(iv) Draw the structures of the two isomers of **J**.

[2]

[Total: 10]

14.3 Hydrocarbons as fuels

116. 9701_w18_qp_21 Q: 3

Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example $CHCl_3$.

(a) $CHCl_3$ is a colourless liquid with a high vapour pressure.

(i) Explain what is meant by *high vapour pressure*.

.....

.....

.....

..... [2]

(ii) An important reaction of $CHCl_3(g)$ is the manufacture of $CHClF_2(g)$, using the following reversible reaction.

$$CHCl_3(g) + 2HF(g) \rightleftharpoons CHClF_2(g) + 2HCl(g)$$

Use the data to calculate the enthalpy change of reaction, ΔH_r, for the formation of $CHClF_2(g)$ as shown in the equation.

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$CHCl_3(g)$	–103.2
$CHClF_2(g)$	–482.2
HF(g)	–273.3
$HCl(g)$	–92.3

enthalpy change of reaction, ΔH_r = ... kJ mol^{-1} [3]

(iii) The reaction in **(ii)** is carried out using a heterogeneous catalyst.

Explain fully the meaning of the terms *heterogeneous* and *catalyst*.

heterogeneous .....

.....

.....

catalyst .....

.....

.....

.....

[3]

(b) $CHCl F_2$ was used as an alternative to chlorofluorocarbons (CFCs). $CHCl F_2$ should no longer be used because it was found to contribute to the *enhanced greenhouse effect*.

(i) Give the meaning of the term *enhanced greenhouse effect*.

.....

..... [1]

(ii) Explain how $CHCl F_2(g)$ may contribute to this effect.

.....

.....

..... [2]

(iii) Suggest another environmental problem associated with the use of $CHCl F_2$.

..... [1]

(c) $CHCl F_2$ is also used to produce the monomer tetrafluoroethene, C_2F_4.

This monomer can be used to produce poly(tetrafluoroethene), PTFE.

(i) State the type of polymerisation that occurs during the production of PTFE.

..... [1]

(ii) Draw the repeat unit of PTFE.

[1]

(iii) Suggest why PTFE is used as a coating for cooking pans.

.....

.....

.....

..... [1]

(iv) Waste disposal can cause litter problems.

State two **other** difficulties associated with the disposal of PTFE.

1 .....

.....

2 .....

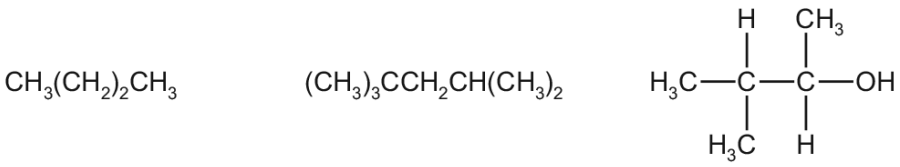
.....

[2]

[Total: 17]

117. 9701_m16_qp_22 Q: 4

The following compounds were all found to be components of a sample of petrol.



G **H** **J**

(a) (i) Give the **molecular** formula of compound **G**.

..... [1]

(ii) Give the **empirical** formula of compound **H**.

..... [1]

(iii) Draw the **skeletal** formula of compound **J**.

[1]

(b) Write an equation to represent the complete combustion of compound **H**.

..... [1]

(c) Fossil fuels are often contaminated with sulfur.

State and explain why supplies of fossil fuels that contain sulfur pose a problem to the environment.

.....

.....

..... [2]

(d) The boiling points of compounds **G**, **H** and **J** are shown below.

compound	**G**	**H**	**J**
boiling point / °C	0	99	112

Explain the differences in the boiling points of the three compounds.

.....

.....

.....

.....

.....

.....

..... [4]

(e) Compound **J** can be produced from 2-chloro-3-methylbutane, $C_5H_{11}Cl$.

Give the reagent(s) and conditions for this reaction.

..... [1]

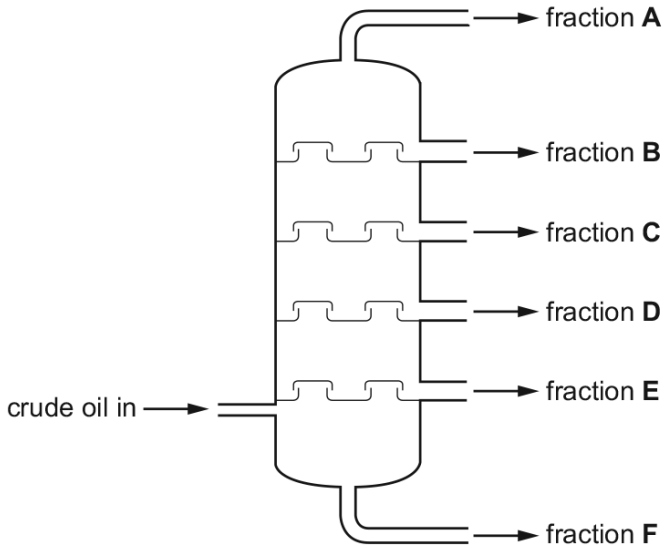
[Total: 11]

118. 9701_s16_qp_23 Q: 3

Crude oil is a mixture of hydrocarbons and provides many useful chemicals when processed.

Two of the stages involved in the processing of crude oil are fractional distillation and cracking.

(a) The diagram is a simplified representation of a fractional distillation column.



(i) What has to be done to the crude oil before it enters the column?

..... [1]

(ii) What trend in **structure** is there from fraction **A** to fraction **F**?

.....

..... [1]

(iii) State the trends in **two** properties of the fractions from **A** to **F**.

.....

.....

..... [2]

(b) The naphtha fraction from fractional distillation of crude oil is used as a starting material for cracking.

(i) Write an equation for the cracking of $C_{12}H_{26}$ to form the products ethene and one other hydrocarbon in a 2 : 1 mole ratio.

..... [1]

(ii) Suggest a use for each of the products from your equation in **(i)**. Explain what makes each product from **(i)** suitable for the use you suggest.

use of ethene .....

.....

explanation .....

.....

use of other product .....

.....

explanation .....

.....

[4]

(c) Burning hydrocarbons can cause a number of environmental problems.

The products of internal combustion engines can include oxides of nitrogen and oxides of carbon.

Sulfur dioxide is a by-product of burning coal in power stations.

(i) Explain how and why oxides of nitrogen are produced in internal combustion engines.

.....

.....

..... [2]

(ii) Write an equation for the reaction between nitrogen monoxide and carbon monoxide in a catalytic converter.

..... [1]

(iii) Write equations to show the involvement of nitrogen monoxide in the formation of acid rain from atmospheric sulfur dioxide.

.....

.....

..... [3]

(iv) Describe two of the problems associated with acid rain.

.....

.....

..... [2]

[Total: 17]

1.

Which substance in a vehicle exhaust results from incomplete combustion of a hydrocarbon fuel?

A CO **B** H_2O **C** N_2 **D** NO

[2002 M/J (24)]

2.

Which compounds would be formed in the reaction of ethene with aqueous bromine in the presence of sodium chloride?

1 CH_2ClCH_2Cl

2 CH_2BrCH_2Cl

3 CH_2BrCH_2Br

[2002 M/J (38)]

3.

Chloroethane is used as a starting material for the production of 'time-release capsules' in pharmaceutical products. One way of preparing chloroethane is to react chlorine and ethane in the presence of ultraviolet light.

Which statement is correct about the **first** stage of the mechanism of this reaction?

A The Cl – Cl bond is split homolytically.

B The Cl – Cl bond is split heterolytically.

C The C – H bond is split homolytically.

D The C – H bond is split heterolytically.

[2002 O/N (22)]

4.

Chlorofluorocarbons (CFCs) have been widely used in aerosol sprays, refrigerators and in making foamed plastics, but are now known to destroy ozone in the upper atmosphere.

Which of the following will not destroy ozone, and therefore can be used safely as a replacement for CFCs?

A $CHBr_3$ **B** CCl_3CBr_3 **C** $CHClFCClF_2$ **D** $CH_3CH_2CH_2CH_3$

[2002 O/N (25)]

5.

When octane is subjected to catalytic cracking, which compounds can be obtained?

1 $CH_2=CH_2$

2 $CH_3CH_2CH=CH_2$

3 $CH_3(CH_2)_4CH_3$

[2002 O/N (38)]

6.

Which pollutant is formed in the internal combustion engine and, if not removed by the catalytic converter, may become involved in the formation of acid rain?

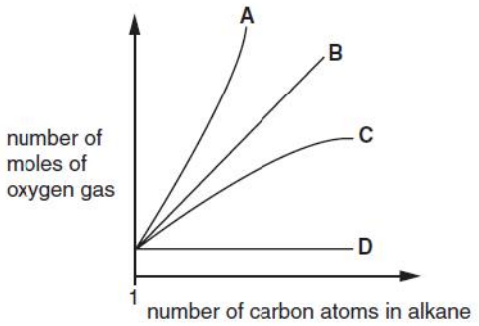
A C **B** C_8H_{18} **C** CO **D** NO

[2003 M/J (19)]

7.

The complete combustion of alkanes to produce carbon dioxide and water is an important exothermic reaction.

Which line on the graph shows the relationship between the number of carbon atoms in the alkane and the number of moles of oxygen gas needed for complete combustion of the alkane?

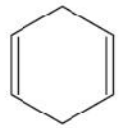


[2003 M/J (23)]

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8.

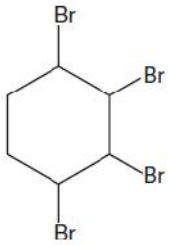
Cyclohexa-1,4–diene is treated with a solution of bromine in tetrachloromethane.



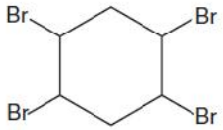
cyclohexa-1,4-diene

Which product is formed?

A



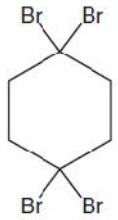
B



C



D



[2003 M/J (24)]

9.

The reaction scheme outlines the production of one of the monomers of nylon 66 from compound **X**.

$$\text{compound X} \xrightarrow[\text{in ethanol}]{\text{KCN}} \text{NCCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CN} \xrightarrow{\text{reduction}} \text{H}_2\text{N(CH}_2\text{)}_6\text{NH}_2$$

Which compound could be **X**?

A $BrCH_2CH_2CH_2CH_2Br$

B $CH_2{=}CHCH{=}CH_2$

C $HOCH_2CH_2CH_2CH_2OH$

D $HO_2CCH_2CH_2CH_2CH_2CO_2H$

[2003 M/J (26)]

10.

In a preparation of ethene, ethanol is added a drop at a time to a heated reagent **Y**. To purify the ethene it is bubbled through a solution **Z** and then collected.

What could reagent **Y** and solution **Z** be?

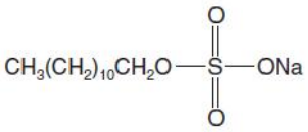
	reagent **Y**	solution **Z**
A	acidified $K_2Cr_2O_7$	dilute NaOH
B	concentrated H_2SO_4	dilute H_2SO_4
C	concentrated H_2SO_4	dilute NaOH
D	ethanolic NaOH	concentrated H_2SO_4

[2003 M/J (29)]

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11.

Long-chain alkanes are converted on an industrial scale into alkylsulphates for use as detergents, e.g. sodium lauryl sulphate.



sodium lauryl sulphate

What deductions about the properties of this substance can be made from this structure?

1 Part of the structure is polar and is water–attracting.

2 The alkyl chain is soluble in oil droplets.

3 All the C-C-C bond angles are tetrahedral.

[2003 M/J (32)]

12.

Hydrogen bromide reacts with ethene to form bromoethane.

What is the best description of the organic intermediate in this reaction?

A It contains carbon, hydrogen and bromine.

B It has a negative charge.

C It is an electrophile.

D It is a free radical.

[2003 O/N (21)]

13.

On strong heating a hydrocarbon produces ethene, propane and but-1-ene in the mole ratio 5 : 1 : 1.

What is the molecular formula of the hydrocarbon?

A $C_{17}H_{34}$ **B** $C_{17}H_{36}$ **C** $C_{19}H_{38}$ **D** $C_{19}H_{40}$

[2003 O/N (22)]

14.

Which molecules would be present in the photochemical chlorination of methane?

1 hydrogen

2 hydrogen chloride

3 dichloromethane

[2003 O/N (36)]

15.

Which compound could **not** be obtained from cracking a sample of nonane, $CH_3(CH_2)_7CH_3$?

A $CH_3CH{=}CHCH{=}CHCH_2CH_2CH_2CH_3$

B $CH_3CH_2CH_2CH_2CH_3$

C $CH_3CH_2CH_2CH_2CH_2CH{=}CH_2$

D $(CH_3CH_2CH_2)_3CH$

[2004 M/J (23)]

16.

In which way are ethene and propane similar?

$CH_2{=}CH_2$ ethene $\qquad$ $CH_3CH_2CH_3$ propane

A They are both obtained by the dehydration of alcohols.

B They are both neutral to an indicator solution.

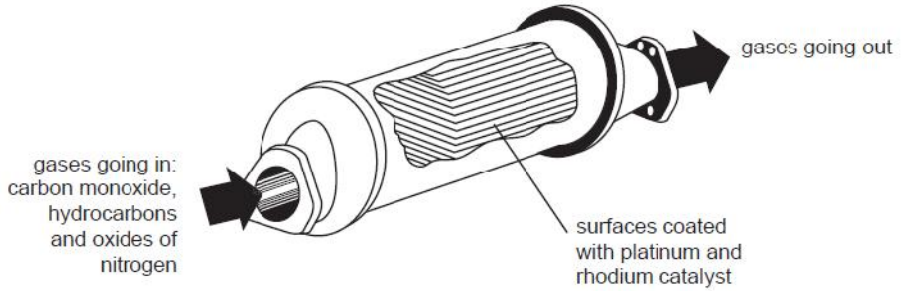
C They can both be hydrogenated using a suitable catalyst.

D They can both undergo polymerisation under suitable conditions.

[2004 M/J (24)]

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17.
Which reaction in the catalytic converter does **not** remove hazardous and polluting gases from the exhaust fumes of a motor car?



These equations are qualitative and unbalanced.
[HC = unburnt hydrocarbons; NO_x = oxides of nitrogen]

A $HC + NO_x \rightarrow H_2O + CO + N_2$

B $CO + NO_x \rightarrow CO_2 + N_2$

C $HC + NO_x \rightarrow H_2O + CO_2 + N_2$

D $CO + O_2 \rightarrow CO_2$

[2004 M/J (25)]

18.
Ethene reacts with aqueous bromine to give two products, CH_2BrCH_2Br and CH_2BrCH_2OH.

Which statement is correct for these products?

A Both products are obtained in this reaction by electrophilic substitution.

B Both products are obtained in this reaction by nucleophilic addition.

C Both products can be hydrolysed to form the same diol.

D Both products can form hydrogen bonds with water.

[2004 M/J (27)]

19.
Instead of obtaining buta-1,3-diene from fossil fuel sources, it is proposed to obtain it from ethanol, which can be obtained from non–food agricultural crops. The sequence of reactions is as follows.

$$CH_3CH_2OH \xrightarrow{\text{step I}} CH_3CHO \xrightarrow{\text{step II}} CH_3CH(OH)CH_2CHO \xrightarrow{\text{step III}} CH_2{=}CHCH{=}CH_2$$
buta-1,3-diene

Which term could be used to describe step I?

A condensation

B dehydration

C dehydrogenation

D hydrogenation

[2004 O/N (22)]

20.
How many different substitution products are possible, in principle, when a mixture of bromine and ethane is allowed to react?

A 3 **B** 5 **C** 7 **D** 9

[2004 O/N (23)]

21.
Which reaction occurs with saturated hydrocarbons?

A catalytic hydrogenation

B ready decolourisation of aqueous bromine

C polymerisation

D thermal cracking

[2004 O/N (25)]

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22.
The reaction of chlorine with methane is carried out in the presence of light.

What is the function of the light?

A to break the C–H bonds in methane

B to break up the chlorine molecules into atoms

C to break up the chlorine molecules into ions

D to heat up the mixture

[2004 O/N (26)]

23.
Which compounds may result from mixing ethane and chlorine in the presence of sunlight?

1 CH_3CH_2Cl

2 $CH_3CH_2CH_2CH_3$

3 $CH_3CHClCHClCH_3$

[2004 O/N (37)]

24.
When bromine reacts with propene in an organic solvent at room temperature, what is the mechanism by which the bromine attacks the propene?

A electrophilic addition

B electrophilic substitution

C nucleophilic addition

D nucleophilic substitution

[2005 M/J (22)]

25.
Which compounds can be obtained from ethene in a **single** reaction?

1 CH_3CH_3

2 $-(-CH_2CH_2-)_n-$

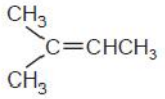
3 $HOCH_2CH_2OH$

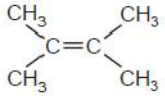
[2005 M/J (38)]

26.
Which hydrocarbon, on treatment with hot acidified potassium manganate(VII), would give ethanoic acid **only**?

A $CH_3CH=CH_2$

B $CH_3CH=CHCH_3$

C 

D 

[2005 O/N (21)]

27.
Compound **X** on reaction with hot concentrated sulphuric acid gave a mixture of **three** alkenes.

What could **X** be?

A butan-2-ol

B propan-2-ol

C 2-methylbutan-2-ol

D 2-methylpropan-2-ol

[2005 O/N (24)]

28.
Modern cars are fitted with catalytic converters. These remove carbon monoxide, unburnt hydrocarbons and oxides of nitrogen from exhaust gases.

Which of these pollutant gases are removed by oxidation?

1 carbon monoxide

2 hydrocarbons

3 nitrogen oxides

[2005 O/N (39)]

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29.

The sex-attractant of the house-fly is muscalure, with the following formula.

$$CH_3(CH_2)_7CH=CH(CH_2)_{12}CH_3$$

Which statements about muscalure are correct?

1 It will decolourise aqueous bromine.

2 It will be oxidised by cold aqueous alkaline $KMnO_4$ to give a diol.

3 It will be optically active.

[2005 O/N (40)]

30.

Light initiates the following reaction.

alkane + chlorine → chloroalkane + hydrogen chloride

What happens to chlorine in this photochemical reaction?

A heterolytic fission to give an electrophile

B homolytic fission to give an electrophile

C heterolytic fission to give a free radical

D homolytic fission to give a free radical

[2006 M/J (24)]

31.

Which equation or statement describes what happens when poly(propene) is burned in an excess of air?

A $(C_3H_6)_n + 1\frac{1}{2}nO_2 \rightarrow 3nC + 3nH_2O$

B $(C_3H_6)_n + 4\frac{1}{2}nO_2 \rightarrow 3nCO_2 + 3nH_2O$

C $(C_3H_6)_n + 6nO_2 \rightarrow 3nCO_2 + 3nH_2O$

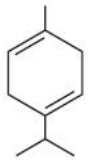
D Poly(propene) does not burn.

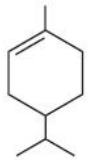
[2006 O/N (25)]

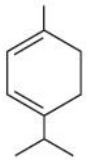
32.

The following three hydrocarbons all occur naturally.

Which of these will be split into two organic compounds, both containing a ketone group, when treated with hot acidified potassium manganate(VII)?

1 

2 

3 

[2006 O/N (37)]

33.

In which reaction is a carbocation (carbonium ion) an intermediate?

A $CH_2=CH_2 + Br_2 \longrightarrow CH_2BrCH_2Br$

B $CH_3CH_2Br + NaOH \longrightarrow CH_3CH_2OH + NaBr$

C $CH_3CH_3 + Cl_2 \longrightarrow CH_3CH_2Cl + HCl$

D $CH_3CHO + HCN \xrightarrow{CN^-} CH_3CH(OH)CN$

[2007 M/J (22)]

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34.

Tetramethyl-lead(IV), $(CH_3)_4Pb$, increases the rate of the reaction of methane with chlorine.

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

Why can tetramethyl-lead(IV) behave in this way?

A It is a source of methyl radicals.

B It releases $CH_3^+(g)$.

C It reacts with chloromethane and prevents equilibrium being established.

D Metal ions catalyse the reaction.

[2007 O/N (21)]

35.

Which reaction occurs when ethane and chlorine are mixed in diffused sunlight?

A a free-radical substitution with hydrogen given off

B a free-radical substitution with hydrogen chloride given off

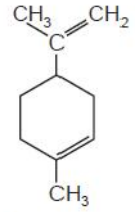
C a free-radical substitution with no gas given off

D a nucleophilic substitution with hydrogen chloride given off

[2007 O/N (22)]

36.

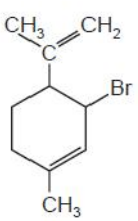
Limonene is an oil formed in the peel of citrus fruits.



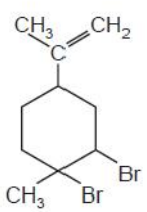
limonene

Which product is formed when molecular bromine reacts with limonene at room temperature in the dark?

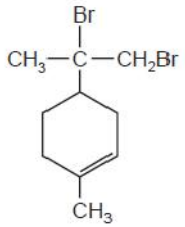
A



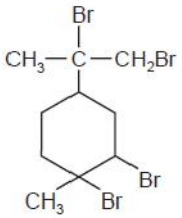
B



C



D



[2007 O/N (23)]

37.

Which pair of reaction types is illustrated by the reaction sequence below?

$$CH_3CH{=}CHCH_3 \xrightarrow{HI \text{ in } CH_3CO_2H} CH_3CH_2CHICH_3 \xrightarrow{NaOH(aq)} CH_3CH_2CH(OH)CH_3$$

A electrophilic addition and electrophilic substitution

B electrophilic addition and nucleophilic substitution

C nucleophilic addition and electrophilic substitution

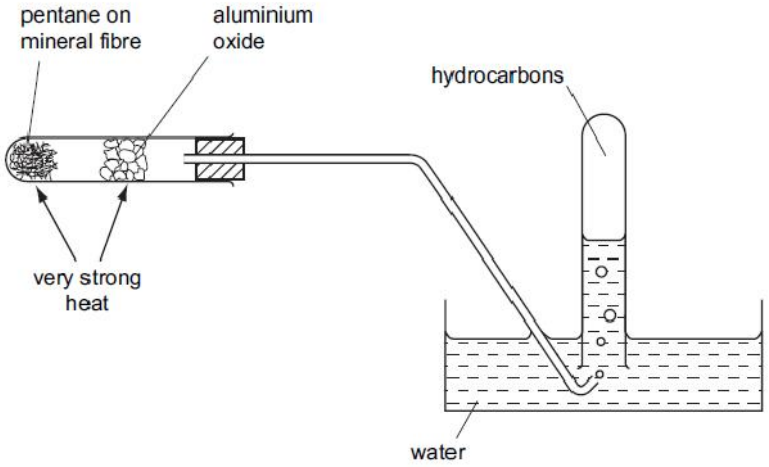
D nucleophilic addition and nucleophilic substitution

[2008 M/J (20)]

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38.

Which hydrocarbon would **not** be collected in the inverted tube by heating pentane, $CH_3(CH_2)_3CH_3$, in the apparatus shown?



A CH_4

B CH_3CH_3

C $CH_3CH_2CH=CH_2$

D $CH_3(CH_2)_8CH_3$

[2008 M/J (23)]

39.

Which hydrocarbon can form a monochloro-substitution derivative which shows **both** chirality **and** *cis-trans* isomerism?

A $CH_3CH=CH_2$

B $(CH_3)_2C=CH_2$

C $CH_3CH=C(CH_3)_2$

D $CH_3CH=CHCH_2CH_3$

[2008 O/N (22)]

40.

Which statements about alkenes are correct?

1 They are formed when higher alkanes are cracked.

2 They are used as monomers for polymerisation.

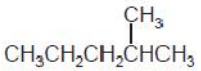
3 They are less reactive than alkanes towards electrophiles.

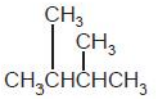
[2008 O/N (37)]

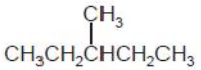
41.

During the bromination of methane, the free radical $CH_3^{\bullet}$ is generated and a possible terminating step of this reaction is the formation of C_2H_6 by the combination of two free radicals.

What could be produced in a terminating step during the bromination of propane?

1 

2 

3 

[2008 O/N (39)]

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42.

A fraction of distilled crude oil contains molecules with between 15 and 19 carbon atoms. This fraction is cracked by strong heating.

Why is this done?

1 To produce alkenes.

2 To produce smaller molecules which are in higher demand.

3 To insert oxygen atoms into the hydrocarbons.

[2009 M/J (37)]

43.

Bromine reacts with ethene to form 1,2-dibromoethane.

What is the correct description of the organic intermediate in this reaction?

A It has a negative charge.

B It is a free radical.

C It is a nucleophile.

D It is an electrophile.

[2009 O/N-11 (25)]

44.

Which equation represents a valid propagation step in the free radical reaction between ethane and chlorine?

A $C_2H_6 + Cl^{\bullet} \rightarrow C_2H_5Cl + H^{\bullet}$

B $C_2H_5Cl + Cl^{\bullet} \rightarrow C_2H_4Cl^{\bullet} + HCl$

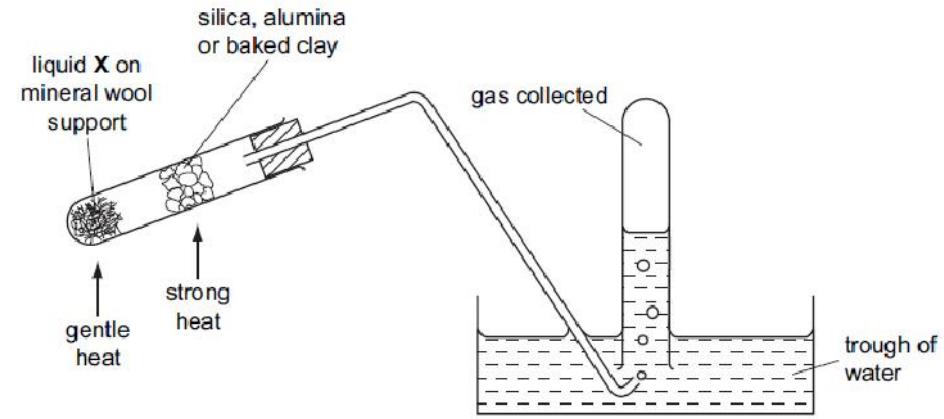
C $C_2H_6 + H^{\bullet} \rightarrow C_2H_5^{\bullet} + HCl$

D $C_2H_5^{\bullet} + Cl^{\bullet} \rightarrow C_2H_5Cl$

[2009 O/N-11 (26)]

45.

The diagram shows an experiment.



Which processes could be demonstrated by using the above apparatus?

1 the oxidation of ethanol (the liquid **X**)

2 the dehydration of ethanol (the liquid **X**)

3 the cracking of paraffin (the liquid **X**)

[2009 O/N-11 (39)]

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1. Nov/2020/Paper_41/No.7

Phenol, C_6H_5OH, is a weak acid.

(a) Phenol can be made from phenylamine, $C_6H_5NH_2$.

Give the reagents and conditions for this reaction.

.....

..... [2]

(b) Phenol reacts with dilute aqueous nitric acid under room conditions to give a mixture of two isomeric products with molecular formula $C_6H_5NO_3$.

Use the *Data Booklet* to draw the structural formulae of these two products in the boxes and name each product.

name .....

name .....

[2]

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(c) Phenol reacts with an excess of aqueous bromine.

(i) Draw and name the organic product of this reaction in the box.

name .....

[2]

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(ii) Describe **two** visual observations that can be made when phenol reacts with an excess of aqueous bromine.

observation 1 .....

observation 2 .....

[1]

(d) Write an equation for a neutralisation reaction in which phenol behaves as an acid.

..... [1]

(e) Water, phenol and ethanol can all behave as acids.

Place these three compounds in order of acidity, starting with the **most** acidic.
Explain your answer.

..... > ..... > .....

most acidic least acidic

.....

.....

.....

.....

.....

.....

[3]

[Total: 11]

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2. Nov/2020/Paper_41/No.8

Benzene, C_6H_6, can be obtained from crude oil.

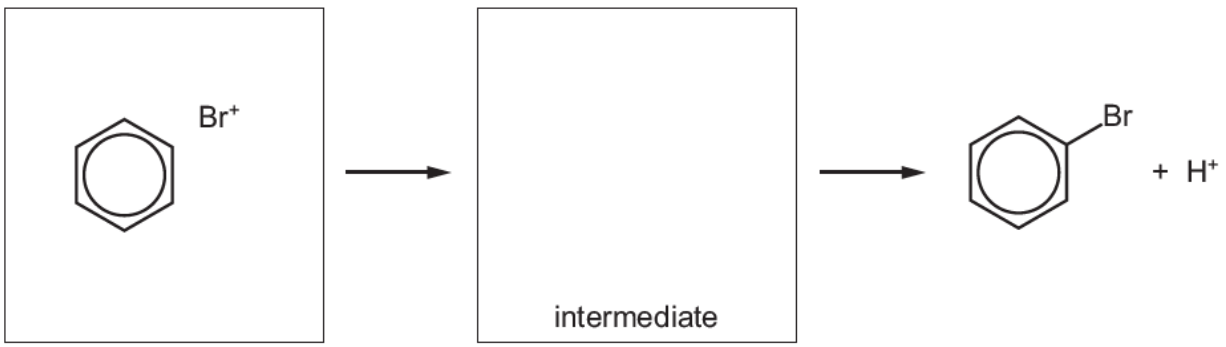
(a) Benzene reacts with bromine, in the presence of a suitable catalyst, forming bromobenzene as one product.

(i) Give the name or formula of the other product of this reaction.

..... [1]

(ii) In the presence of the catalyst, bromine can be considered to form the electrophile Br^+.

Complete the mechanism by which benzene reacts with Br^+, using curly arrows to show the movement of electron pairs.



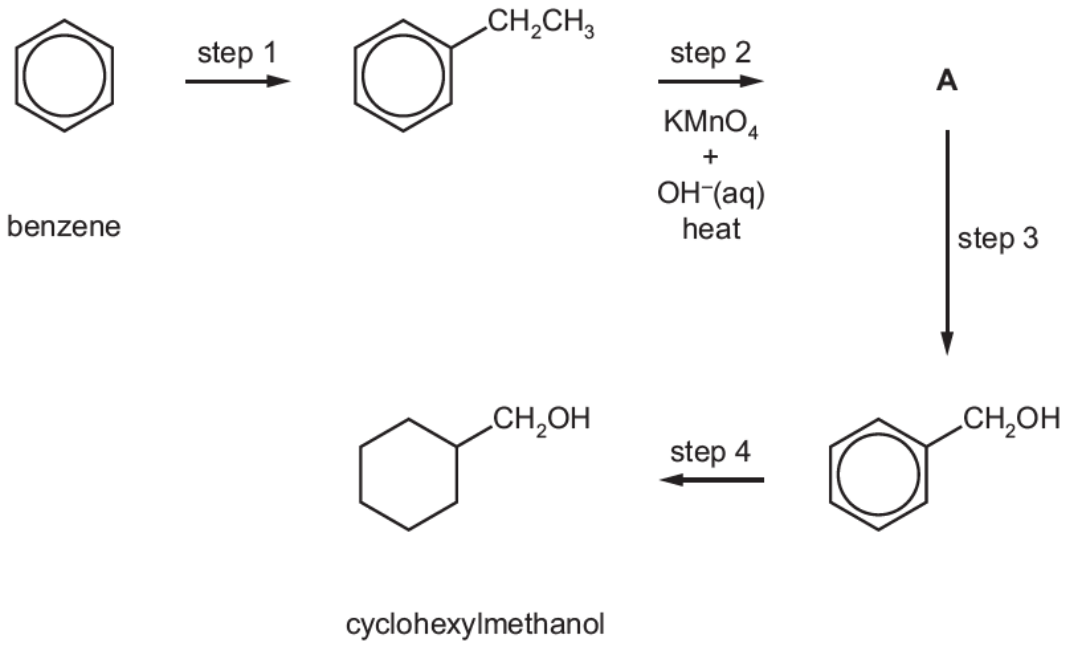
[2]

(iii) Name this mechanism.

..... [1]

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(b) Benzene can be used as a starting material in the synthesis of cyclohexylmethanol, $C_6H_{11}CH_2OH$, as outlined below.



cyclohexylmethanol

(i) Identify a suitable reagent and a suitable catalyst for step 1.

reagent .....

catalyst .....

[2]

(ii) Draw the structure of **A**.

A

[1]

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(iii) Identify suitable reagents for steps 3 and 4.

step 3 .....

step 4 .....

[2]

(iv) Deduce the number of peaks in the carbon-13 NMR spectrum of cyclohexylmethanol.

..... [1]

[Total: 10]

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3. Nov/2020/Paper_42/No.7

(a) Describe the structure of a benzene molecule, C_6H_6.

Your answer should include:

- the shape of the molecule
- the relative lengths of the C–C bonds
- bond angles
- the hybridisation of the carbon atoms
- the overlap between orbitals that produces each type of bond present.

.....

.....

.....

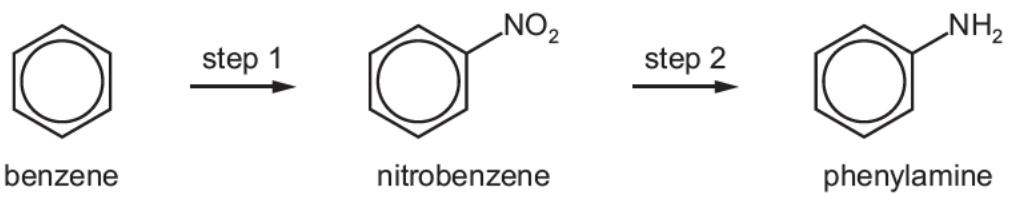
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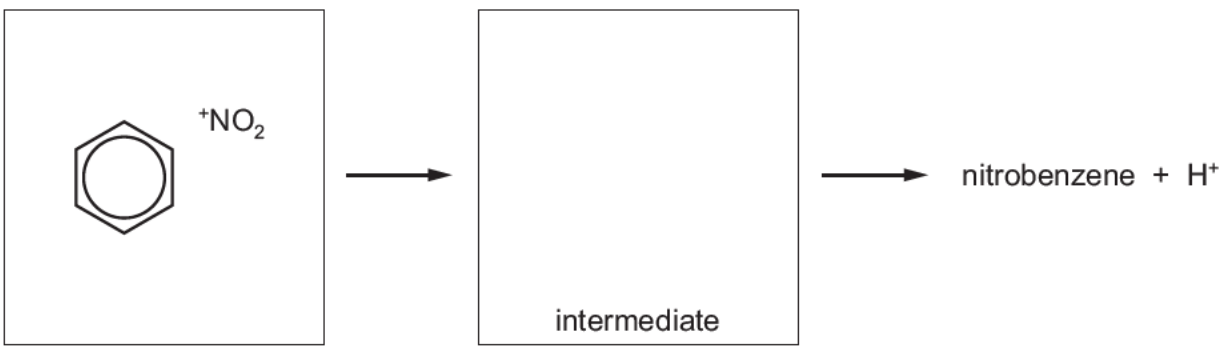
..... [4]

(b) Benzene can be used as a starting material to produce phenylamine by a two-step synthesis.



(i) Step 1 is the reaction of benzene with NO_2^+ ions.

Complete the mechanism and draw the intermediate of step 1.
Include all relevant charges and curly arrows to show the movement of electron pairs.



[2]

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(ii) State the name of the mechanism in **(b)(i)**.

..... [1]

(iii) Identify the reagents needed to produce NO_2^+ ions.

Write an equation to explain how these reagents produce NO_2^+ ions.

.....

.....

..... [2]

(iv) Give reagents and conditions for the production of phenylamine from nitrobenzene in step 2.

.....

..... [2]

(c) Phenylamine reacts with $Br_2(aq)$.

(i) Write an equation for this reaction. You may use structural or displayed formulae.

..... [1]

(ii) Name the organic product of this reaction.

..... [1]

(iii) Describe **two** observations that can be **seen** when phenylamine reacts with $Br_2(aq)$.

observation 1 .....

observation 2 .....

[1]

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(d) Describe the relative basicities of ammonia, ethylamine and phenylamine, starting with the **least** basic.
Explain your answer in terms of their structures.

..... < ..... < .....
least basic most basic

.....

.....

.....

.....

[3]

(e) 1,3-diaminopropane, $H_2NCH_2CH_2CH_2NH_2$, can be used to make polyamides.

(i) Identify **one** compound that would react with 1,3-diaminopropane to form a polyamide.

..... [1]

(ii) Draw a section of the polymer chain formed from 1,3-diaminopropane and the compound you chose in **(e)(i)**.

Your answer should:
- include four monomer residues (two of each type of monomer)
- show the amide link fully displayed
- clearly identify **one** repeat unit of this polymer.

[2]

[Total: 20]

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4. June/2020/Paper_41/No.5

(a) Benzene reacts with bromine in the presence of an aluminium bromide catalyst, $AlBr_3$, to form bromobenzene. This is a substitution reaction. No addition reaction takes place.

(i) Explain why no addition reaction takes place.

.....

..... [1]

$AlBr_3$ reacts with bromine to generate an electrophile, Br^+.

(ii) Draw the mechanism of the reaction between benzene and Br^+ ions. Include all relevant arrows and charges.

[3]

(iii) Write an equation to show how the $AlBr_3$ catalyst is reformed.

..... [1]

(b) Suggest why bromination of phenol occurs more readily than bromination of benzene.

.....

.....

.....

.....

..... [2]

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(c) (i) There are four different carbocations with the same formula, $C_4H_9^+$. One structure is given in the table.

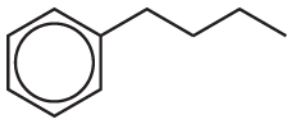
Suggest the structural formulae of the three other carbocations.

structure 1	structure 2	structure 3	structure 4
$CH_3CH_2CH_2CH_2^+$			

[3]

(ii) Benzene reacts with each of these carbocations in separate Friedel-Crafts alkylation reactions.
In each reaction an organic compound with formula $C_{10}H_{14}$ is formed. The number of peaks observed in the carbon-13 NMR spectrum of each compound is given.

Suggest the structures for the three other compounds.

 number of peaks in carbon-13 NMR = 8	number of peaks in carbon-13 NMR = 6
number of peaks in carbon-13 NMR = 7	number of peaks in carbon-13 NMR = 8

[4]

[Total: 14]

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5. June/2020/Paper_42/No.4

(a) (i) When benzene undergoes nitration a nitro group substitutes at a carbon atom.

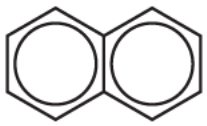
State the shape (geometry) around the substituted carbon atom

- in the benzene molecule, ...
- in the intermediate complex, ...
- in the nitrobenzene product. .....

[2]

(ii) Naphthalene, $C_{10}H_8$, is an arene hydrocarbon.

naphthalene



When naphthalene undergoes nitration, a mixture of two organic compounds is formed. Each compound contains **one** nitro group.

Suggest the structures of these compounds.

structure 1	structure 2

[1]

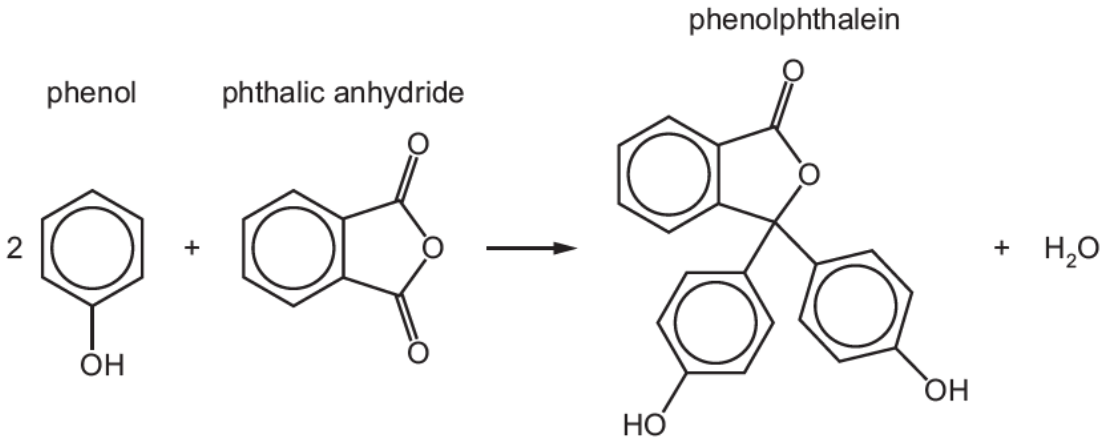
(b) Naphthalene can be oxidised under certain conditions to phthalic anhydride, $C_8H_4O_3$, carbon dioxide and water.

Construct an equation for this reaction. Use [O] to represent an atom of oxygen from the oxidising agent.

..... [1]

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(c) The indicator, phenolphthalein, can be synthesised from phthalic anhydride and phenol under certain conditions.



Deduce the *type of reaction* shown by this equation.

..... [1]

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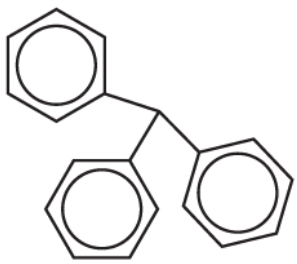
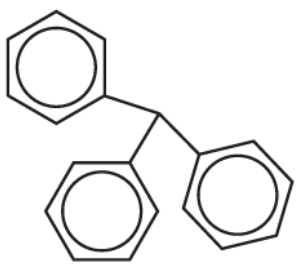
(d) (i) Name the functional groups, in addition to the benzene ring, present in a phenolphthalein molecule.

..... [1]

(ii) Phenolphthalein reacts separately with the two reagents shown in the table.

Complete the table by:

- drawing the structures of the organic products formed (part of the structure has been given for you)
- stating the types of reaction.

reagent	organic product structure	type of reaction
an **excess** of hot NaOH(aq)		
an **excess** of Br_2(aq)		

[4]

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(e) Phenolphthalein is an indicator and is represented by the formula HIn.
Phenolphthalein, HIn, is a weak acid.

$$HIn \rightleftharpoons H^+ + In^-$$

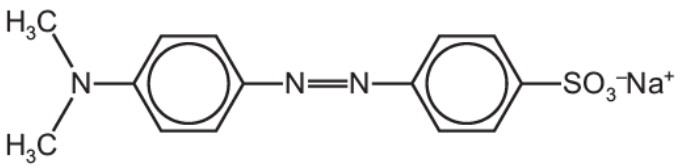
The K_a value for phenolphthalein is 5.0×10^{-10} mol dm^{-3} at 298 K. This indicator changes colour at a pH of approximately 8.8.

Calculate the ratio $\frac{[In^-]}{[HIn]}$ at pH 8.8.

ratio $\frac{[In^-]}{[HIn]}$ = ... [2]

(f) Methyl orange is another acid-base indicator. Its structure in aqueous solution at pH 4.4 is shown.

methyl orange



(i) On the structure of methyl orange, **circle** the bond or bonds that make this compound a dye. [1]

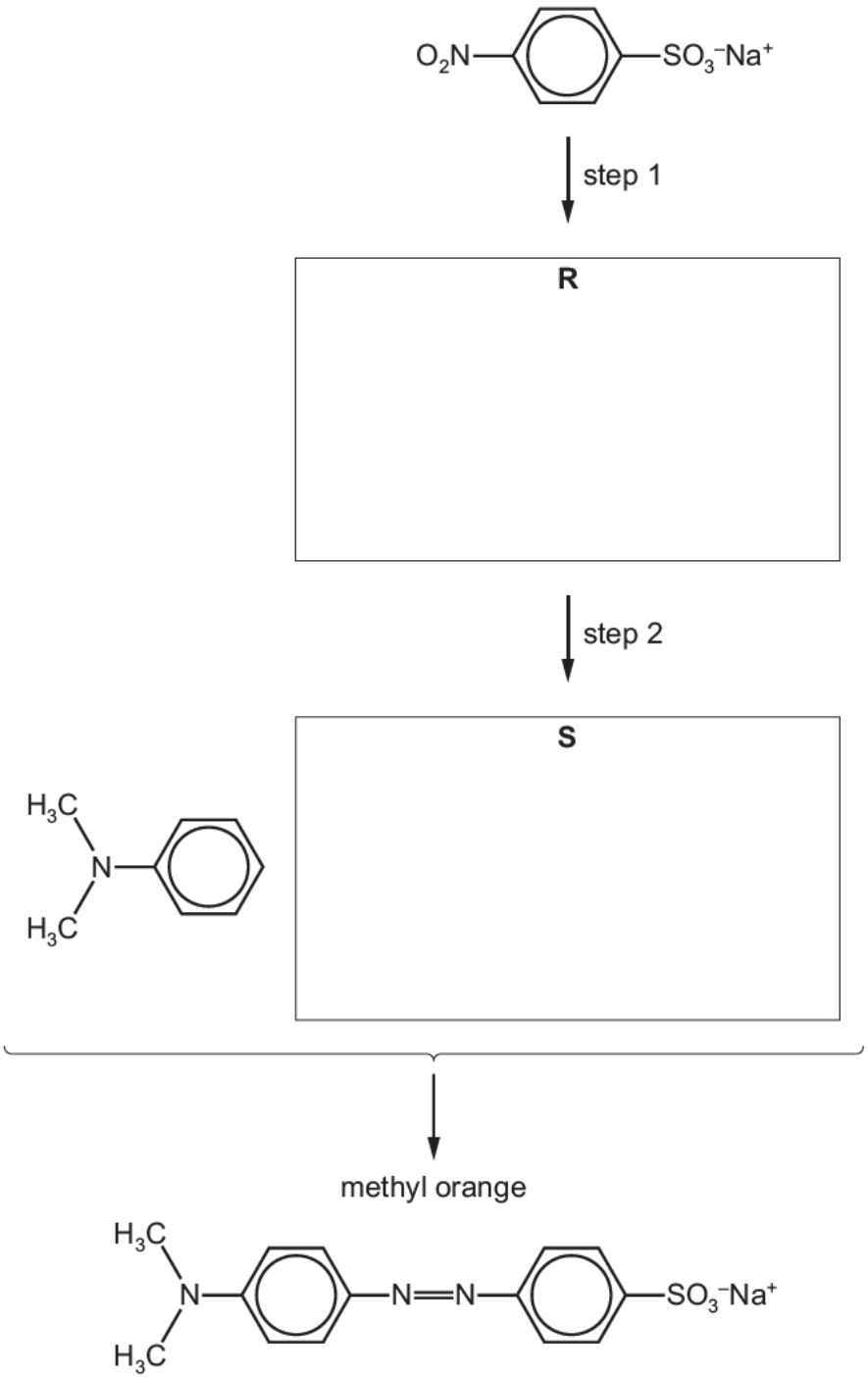
The colour of this indicator changes between pH 3.2 and pH 4.4.

(ii) Suggest the structure of methyl orange at pH 3.0. Assume the $-SO_3^-Na^+$ group is unreactive.

[1]

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(g) Methyl orange can be synthesised as shown.



(i) Deduce the identities of compounds **R** and **S** and draw their structures in the boxes. [2]

(ii) Suggest reagents and conditions for step 1 and step 2.

step 1 .....

step 2 .....

[3]

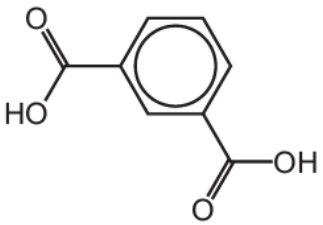
[Total: 19]

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1. Nov/2021/Paper_42/No.7

The structure of benzene-1,3-dicarboxylic acid is shown.

benzene-1,3-dicarboxylic acid



(a) State the empirical formula of benzene-1,3-dicarboxylic acid.

..... [1]

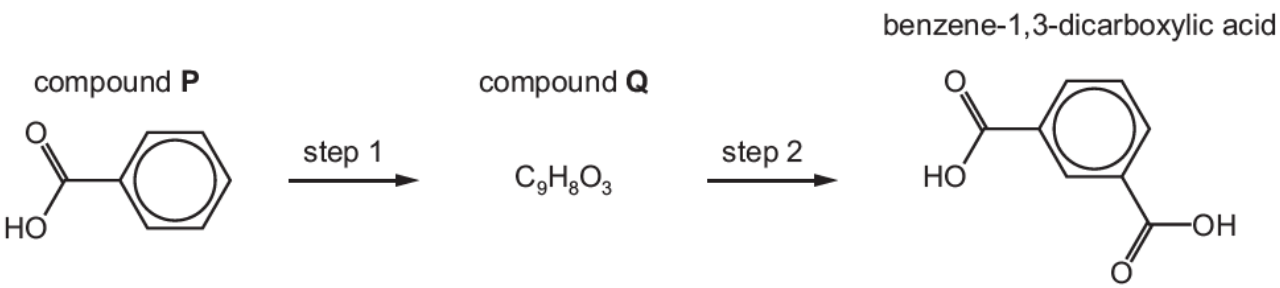
(b) Benzene-1,3-dicarboxylic acid is an isomer of benzene-1,4-dicarboxylic acid. These two isomers can be distinguished by carbon-13 (^{13}C) NMR spectroscopy.

State the number of peaks in the carbon-13 (^{13}C) NMR spectrum of each compound.

benzene-1,3-dicarboxylic acid	
benzene-1,4-dicarboxylic acid	

[2]

(c) Benzene-1,3-dicarboxylic acid can be made by the two-step synthesis shown below.



(i) Name compound **P**.

..... [1]

(ii) Explain why the major product of this two-step synthesis is benzene-1,3-dicarboxylic acid and **not** benzene-1,4-dicarboxylic acid.

.....

..... [1]

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(iii) The reagents used for step 1 are CH_3COCl and $AlCl_3$. These reagents give rise to $CH_3\overset{+}{C}{=}O$ ions which react with compound **P**.

Name the mechanism of this reaction.

..... [1]

(iv) Draw the mechanism of the reaction of $CH_3\overset{+}{C}{=}O$ ions with compound **P**. Include all relevant curly arrows and charges, the structure of the intermediate and the structure of compound **Q**.

intermediate compound **Q**

$CH_3\overset{+}{C}{=}O$



[3]

(v) Suggest a reagent and conditions to convert compound **Q** into benzene-1,3-dicarboxylic acid, in step 2.

..... [1]

[Total: 10]

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2. Nov/2021/Paper_42/No.9

Butylamine, $CH_3CH_2CH_2CH_2NH_2$, can be synthesised from different organic compounds by using suitable reagents. Each reaction involves one step.

(a) Complete the table to describe three different syntheses.

- One of the three syntheses should involve a nucleophilic substitution reaction.
- The starting organic compound for each synthesis should contain a different functional group.
- A different reagent should be used for each synthesis.

starting organic compound	reagent and conditions

[6]

(b) Compare and explain the relative basicities of ammonia, butylamine and phenylamine.

..... > ..... > .....
most basic least basic

.....

.....

.....

.....

.....

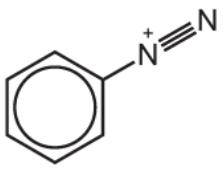
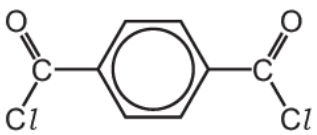
..... [4]

[Total: 10]

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3. Nov/2021/Paper_42/No.10

(a) Complete the table to show the structure of the organic product from each reaction of phenol, C_6H_5OH.

reaction	reaction mixture	structure of organic product
1	phenol + NaOH(aq)	
2	phenol + Na(s)	
3	phenol +  (aq) + NaOH, at 4 °C	
4	an excess of phenol + 	

[4]

(b) Identify **two** reactions from the table in which ethanol would behave in a similar way to phenol.

..... [1]

[Total: 5]

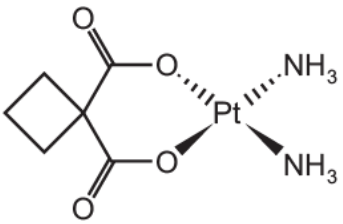
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Hydrocarbons - 2021

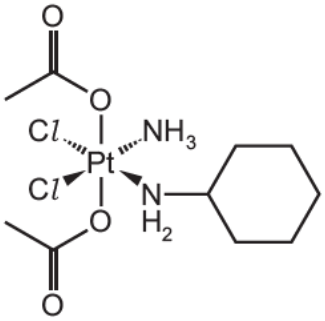
1. March/2021/Paper_42/No.5

(a) Carboplatin and satraplatin are used as anticancer drugs instead of cisplatin.

carboplatin



satraplatin



(i) Describe the action of cisplatin as an anticancer drug.

.....

.....

..... [2]

(ii) Suggest the geometry of the platinum centre in the carboplatin complex.

..... [1]

(iii) Suggest why carboplatin does **not** show cis-trans isomerism.

.....

.....

..... [1]

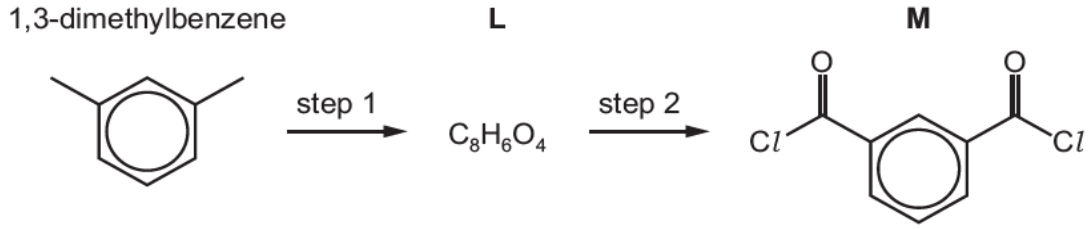
(iv) Satraplatin is a neutral complex, containing the ligands $CH_3CO_2^-$, $C_6H_{11}NH_2$, Cl^- and NH_3.

Deduce the oxidation state of platinum in satraplatin.

..... [1]

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(b) Compound **M** is made from 1,3-dimethylbenzene in a two-step synthesis.



(i) Draw the structure of **L**.

[1]

(ii) Suggest reactants and conditions for each step of this synthesis.

step 1 .....

step 2 .....

[2]

(iii) Write an equation for step 2.

..... [1]

(iv) A student investigates a possible synthesis of **M** directly from benzene using $COCl_2$ in the presence of an $AlCl_3$ catalyst.

Benzene initially reacts with $COCl_2$ as shown.

reaction 1 $COCl_2 + AlCl_3 \rightarrow AlCl_4^- + Cl{-}\overset{+}{C}{=}O$

reaction 2 $C_6H_6 + Cl{-}\overset{+}{C}{=}O \rightarrow C_6H_5COCl + H^+$

Reaction 2 is the electrophilic substitution of $Cl{-}\overset{+}{C}{=}O$ for H^+ in benzene.

Suggest a mechanism for reaction 2.

[3]

[Total: 12]

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1. June/2022/Paper_41/No.4(d, e)

(d) The ligand bipyridine consists of two pyridine rings.

Pyridine, C_5H_5N, and benzene, C_6H_6, have similar planar, cyclic structures.

pyridine



Fig. 4.2

By reference to the hybridisation of the carbon atoms and the nitrogen atom, and orbital overlap, suggest how the σ and π bonds are formed in a pyridine molecule.

.....

.....

.....

.....

..... [3]

(e) Pyridine reacts with Cl_2 in the presence of $AlCl_3$ as shown in Fig. 4.3.

pyridine 3-chloropyridine

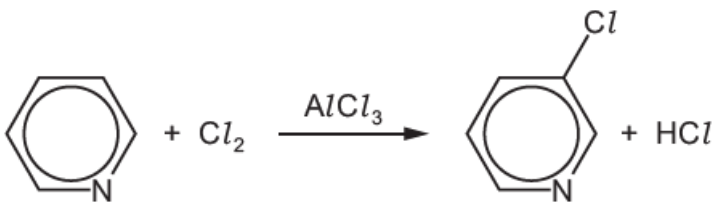


Fig. 4.3

The mechanism of this reaction is similar to that of the chlorination of benzene. $AlCl_3$ reacts with chlorine to generate an electrophile, Cl^+.

Complete the diagram to show the mechanism for the reaction of pyridine with Cl^+. Include all relevant charges, dipoles, lone pairs of electrons and curly arrows as appropriate.



[3]

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2. June/2022/Paper_41/No.7

Procaine is used as an anaesthetic in medicine. It can be synthesised from methylbenzene in five steps as shown in Fig. 7.1.

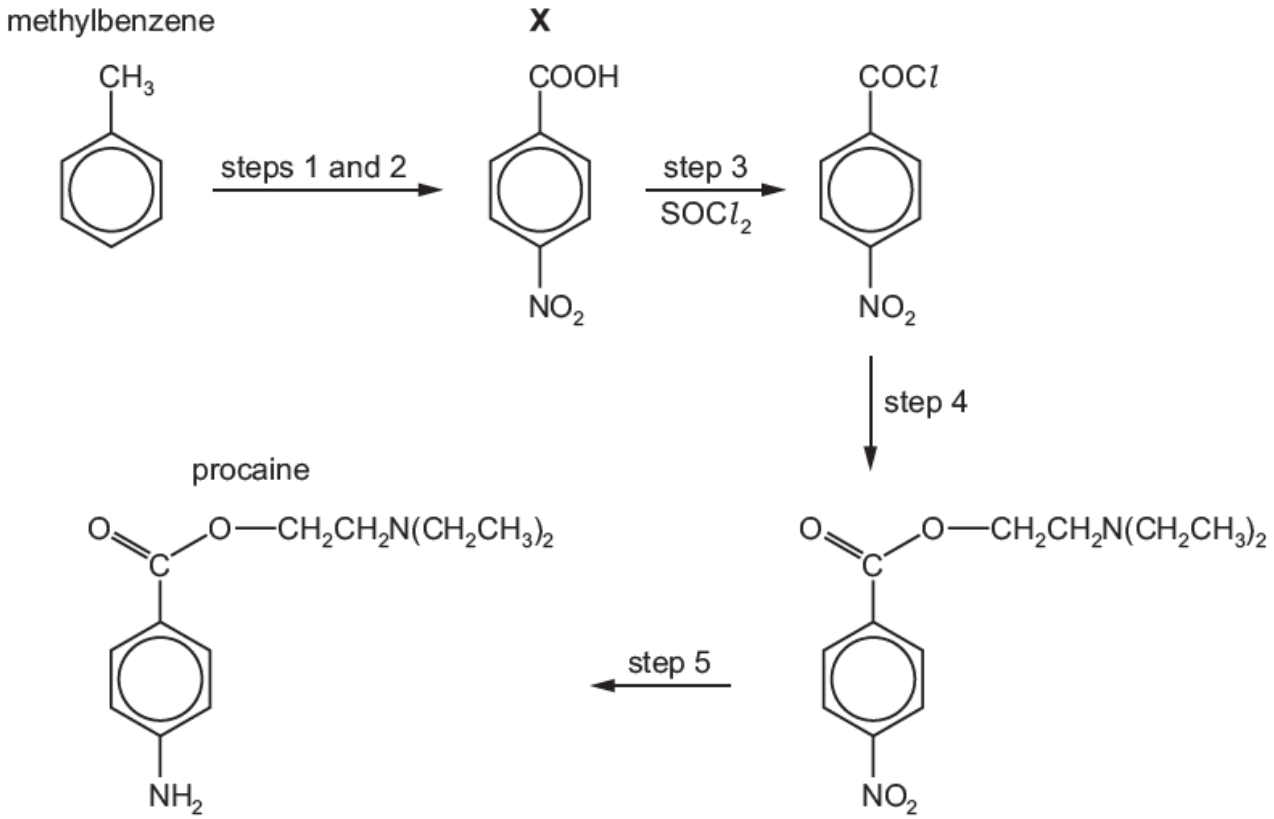


Fig. 7.1

(a) (i) Name all the functional groups present in procaine.

..... [1]

(ii) A molecule of procaine has 13 carbon atoms.

State the number of carbon atoms that are sp, sp^2 and sp^3 hybridised in procaine.

sp carbons = ... sp^2 carbons = ... sp^3 carbons = ... [1]

(b) The proton (^1H) NMR spectrum of procaine dissolved in D_2O is recorded.

Predict the number of peaks observed.

..... [1]

(c) State why procaine can act as a base.

.....

..... [1]

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(d) Compound **X** can be synthesised in two steps from methylbenzene.

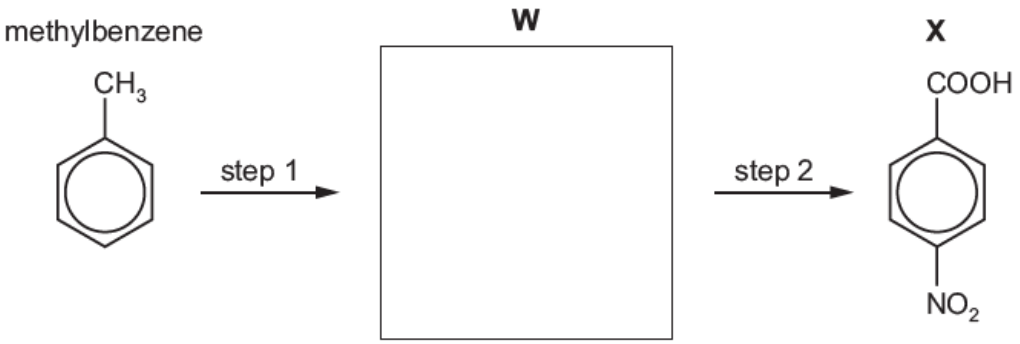


Fig. 7.2

(i) Draw the structure of compound **W** in the box provided. [1]

(ii) State the reagents and conditions for step 1 and step 2.

step 1 .....

step 2 .....

[2]

(e) Procaine is synthesised in three steps from **X**.

Suggest the reagents and conditions for step 4 and for step 5 in Fig. 7.1.

step 4 .....

step 5 .....

[3]

(f) **(i)** Explain what is meant by partition coefficient, K_{pc}.

.....

..... [2]

(ii) The partition coefficient of procaine between octan-1-ol and water is 1.77.

Octan-1-ol and water are immiscible. A solution containing 0.500 g of procaine in 75.0 cm^3 of water is shaken with 50.0 cm^3 of octan-1-ol.

Calculate the mass of procaine that is extracted into the octan-1-ol.

mass of procaine extracted = ... g [2]

[Total: 14]

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3. June/2022/Paper_42No.6(a _ c)

(a) The reagent and conditions required for the nitration of benzene, benzoic acid and phenol are shown in Table 6.1.

Table 6.1

compound	reagents and conditions for nitration
benzene	concentrated HNO_3, 50 °C, concentrated H_2SO_4 catalyst
benzoic acid	concentrated HNO_3, 100 °C, concentrated H_2SO_4 catalyst
phenol	dilute HNO_3(aq), 20 °C

Concentrated HNO_3 reacts with concentrated H_2SO_4 to generate the electrophile NO_2^+.

(i) Complete Fig. 6.1 to show the mechanism of the reaction between benzene and NO_2^+. Include all relevant curly arrows and charges.

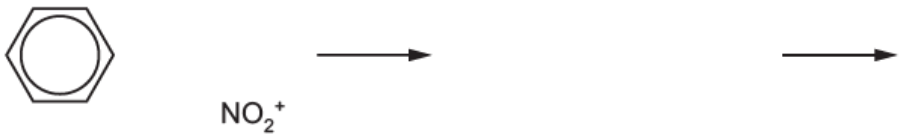


Fig. 6.1

[3]

(ii) Write an equation to show how H_2SO_4 is regenerated.

..... [1]

(b) Draw the major products from the mononitration of benzoic acid and of phenol.

major product from benzoic acid	major product from phenol

[2]

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(c) Compare the relative ease of nitration of benzene, benzoic acid and phenol.
Explain your reasoning; include reference to the structures of the three compounds in your answer.

..... > ..... > .....
easiest least easy

.....

.....

.....

.....

.....

[4]

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1. Nov/2022/Paper_41/No.7

(a) The structure of compound **P** is shown in Fig. 7.1.

P

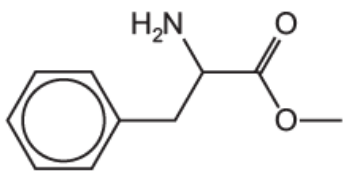


Fig. 7.1

(i) **P** is optically active.

Use an asterisk (*) to identify all chiral carbon atoms on the structure of **P** in Fig. 7.1. [1]

(ii) Plane polarised light is passed through a pure sample of one enantiomer of **P**. This is then repeated with a pure sample of the other enantiomer of **P**.

Describe the results of these two experiments, stating the similarities and differences of the results.

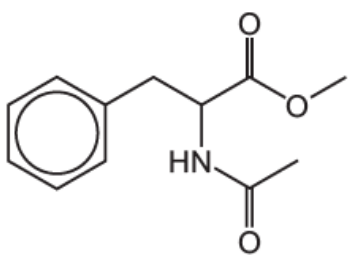
.....

.....

..... [2]

(b) **P** can be used to make compound **Q** in a single step reaction.

Q



(i) Give the structural formula of the compound that is added to **P** to make **Q** and give the formula of the other product of this reaction.

compound added to **P** .....

other product .....

[1]

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(ii) When an ester is treated with $LiAlH_4$ in dry ether the ester linkage is cleaved by the addition of four hydrogen atoms and two alcohols are produced.

Draw the structures of the compounds formed when **Q** is treated with an **excess** of $LiAlH_4$ in dry ether.

[3]

(iii) Compare the relative basicities of compound **P**, compound **Q** and phenylamine.

..... < ..... < .....
least basic most basic

Explain your answer.

.....

.....

.....

.....
[3]

(c) **P** can be used to make compound **R** in a two-step reaction, shown in Fig. 7.2.

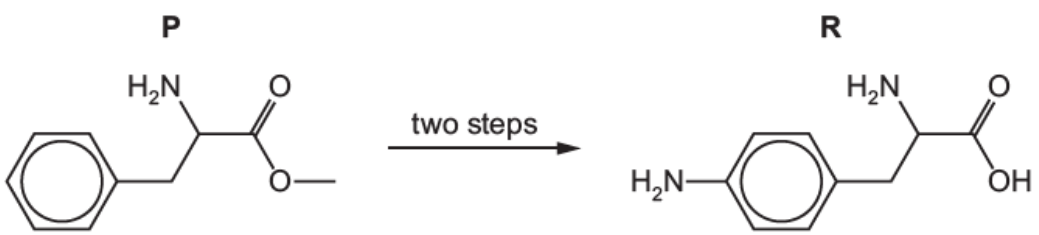


Fig. 7.2

(i) Identify the reagents and conditions used for the two steps of the reaction.

step 1 .....

step 2 .....
[2]

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(ii) Complete Table 7.1 by drawing the structures of the organic products formed when **R** is treated separately with the reagents given.

Table 7.1

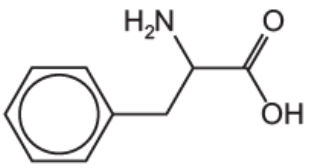
reagent	product
$HNO_2(aq)$ at 4 °C	
an excess of $Br_2(aq)$ at room temperature	

[2]

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(d) **P** can be used to produce compound **T**.

T



(i) In aqueous solution, **T** has a property called an isoelectric point.

Explain what is meant by isoelectric point.

.....

..... [1]

(ii) **T** can polymerise under suitable conditions. No other monomer is involved in this reaction.

Draw a section of the polymer chain formed that includes three **T** monomers. Identify the repeat unit on your diagram.

[2]

[Total: 17]

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2. Nov/2022/Paper_41/No.8

Benzene, C_6H_6, is an aromatic molecule.

(a) State the C–C–C bond angle and the hybridisation shown by the carbon atoms in benzene.

bond angle .....

hybridisation .....

[1]

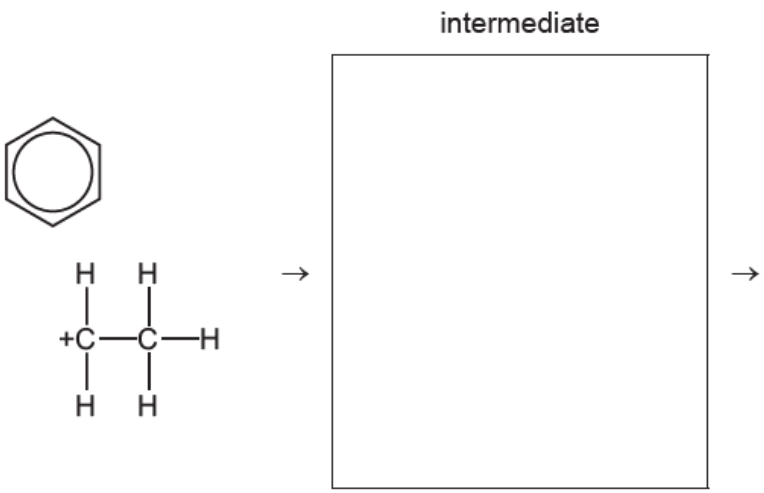
(b) Benzene reacts with chloroethane in the presence of a catalyst. The reaction mechanism is called electrophilic substitution.

(i) The first step in the reaction is the generation of the $^+CH_2CH_3$ electrophile.

Write an equation for the reaction that generates this electrophile.

..... [1]

(ii) Describe the mechanism for the reaction between benzene and the $^+CH_2CH_3$ electrophile. Include all relevant curly arrows and charges.



[3]

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(c) Chlorobenzene and chloroethane have different reactivities in nucleophilic substitution reactions.

(i) Identify a suitable reagent to illustrate this difference in reactivity.

The reagent chosen should give **visibly** different results with chlorobenzene and chloroethane.

..... [1]

(ii) Write equations to describe any reactions that occur.

[1]

(iii) Explain the difference in the reactivities of chlorobenzene and chloroethane in nucleophilic substitution reactions.

.....

..... [1]

[Total: 8]

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(a) The structural and displayed formulae of three aromatic compounds, **A**, **B** and **C**, are shown in Fig. 7.1.

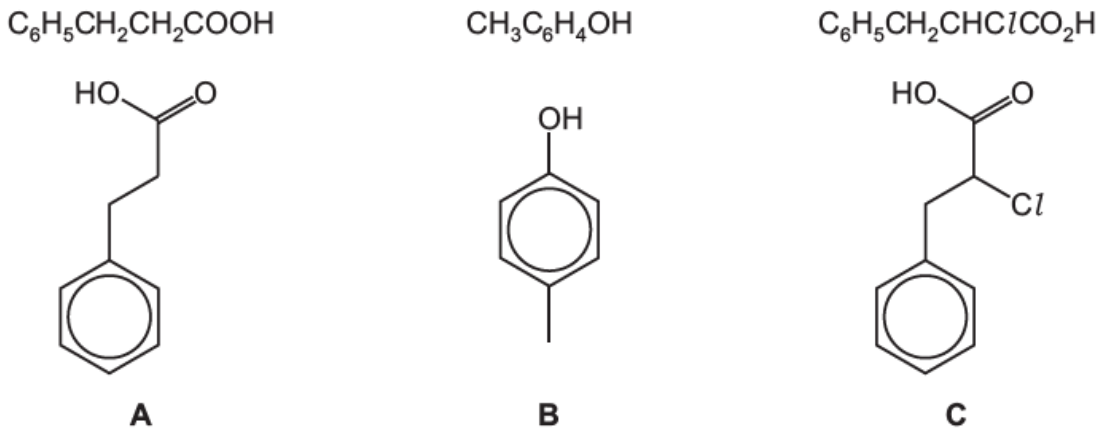


Fig. 7.1

Compare the relative acidities of **A**, **B** and **C**.

..... > ..... > .....
most acidic least acidic

Explain your answer.

.....

.....

.....

..... [3]

(b) Methylbenzene, $C_6H_5CH_3$, can be made from benzene by an electrophilic substitution reaction.

(i) Identify a compound that reacts with benzene to form methylbenzene.
Identify the catalyst used.

compound .....

catalyst .....
[1]

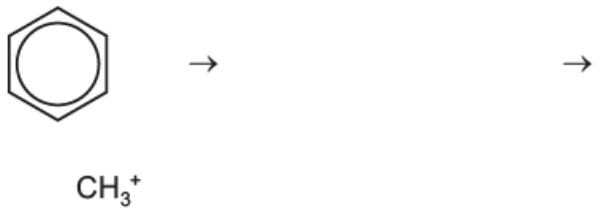
(ii) The first step in the reaction is the generation of the CH_3^+ electrophile.

Write an equation for the reaction that generates this electrophile.

..... [1]

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(iii) Describe the mechanism for the reaction between benzene and the CH_3^+ electrophile. Include all relevant curly arrows and charges.



CH_3^+

[3]

(iv) Identify a suitable reagent to oxidise methylbenzene to benzoic acid, C_6H_5COOH.

Write an equation for this reaction using [O] to represent one atom of oxygen from the oxidising agent.

reagent .....

equation .....

[2]

(v) Methylbenzene and benzoic acid are both nitrated with a mixture of concentrated nitric acid and sulfuric acid to give mononitrated products. The structural formulae of these products are $CH_3C_6H_4NO_2$ and $HOOCC_6H_4NO_2$ respectively.

Draw the structures of these two products.

[1]

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(c) A reaction scheme is shown in Fig. 7.2.

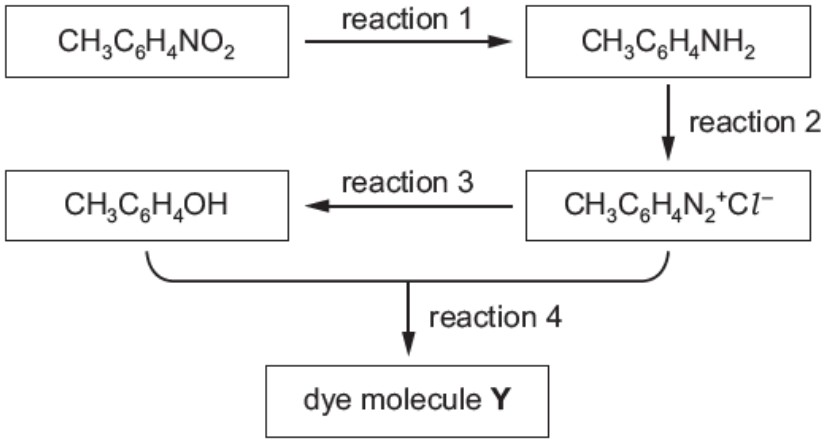


Fig. 7.2

(i) Describe the reagents and conditions to produce $CH_3C_6H_4N_2^+Cl^-$ from $CH_3C_6H_4NH_2$ in reaction 2.

reagents .....

conditions .....

[1]

(ii) Describe how $CH_3C_6H_4OH$ can be produced from $CH_3C_6H_4N_2^+Cl^-$ in reaction 3.

..... [1]

(iii) Draw the structure of the dye molecule **Y** formed when $CH_3C_6H_4N_2^+Cl^-$ and $CH_3C_6H_4OH$ react together in reaction 4. Describe the conditions for this reaction.

structure

conditions .....

[2]

[Total: 15]

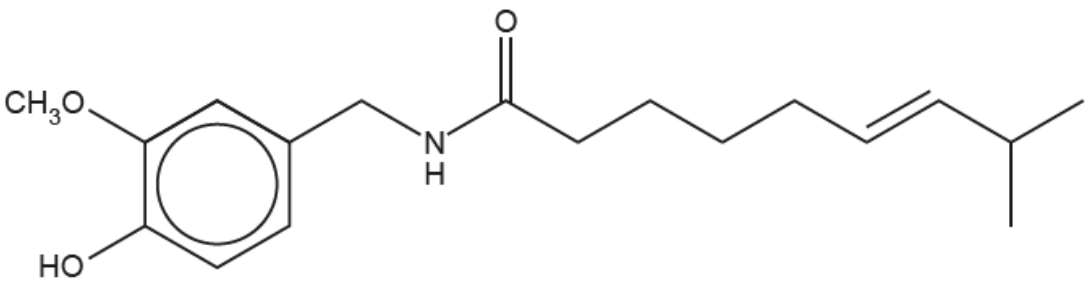
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Hydrocarbons – 2023 A2 Chemistry 9701

1. Nov/2023/Paper_9701/41/No.8(c)

Capsaicin is found in chilli peppers.

capsaicin



You should assume the CH_3O group is unreactive in the reactions involved in this question.

(c) Capsaicin is heated with an excess of hydrogen gas in the presence of platinum metal.

The six-membered ring reacts in the same way as benzene under these conditions.

Draw the structure of the organic product formed.

[2]

2. June/2023/Paper_9701/41/No.4(a)

(a) State the hybridisation of the carbon atoms and the C–C–H bond angle in benzene, C_6H_6. Explain how orbital overlap leads to the formation of σ and π bonds in benzene.

.....

.....

.....

.....

..... [3]

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3. June/2023/Paper_9701/42/No.5(a _ c)

(a) Methylbenzene can undergo different reactions, as shown in Fig. 5.1.

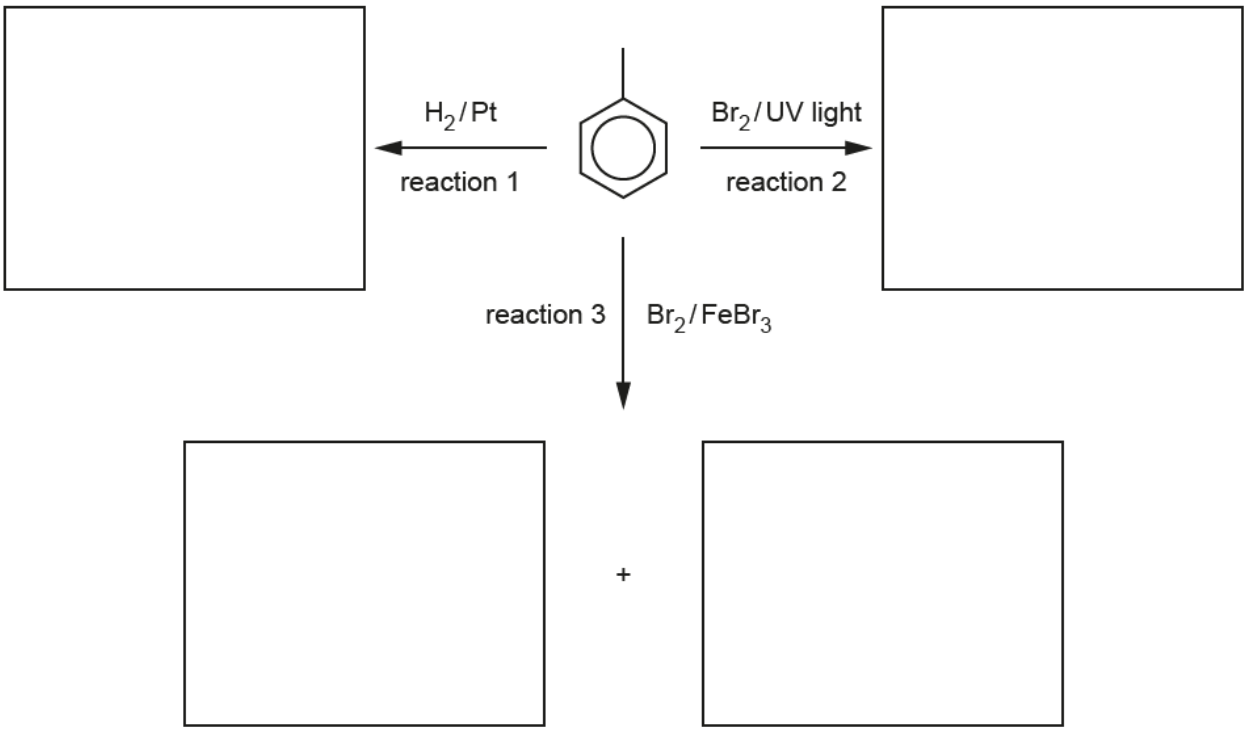


Fig. 5.1

(i) Draw structures in Fig. 5.1 for the possible organic products of the three reactions shown. [3]

(ii) Complete Table 5.1.

Table 5.1

	type of reaction	mechanism
reaction 1		
reaction 2		

[2]

(b) When methylbenzene reacts with an electrophile, a substitution reaction occurs. No addition reaction takes place under these conditions.

Explain why no addition reaction takes place.

.....

..... [1]

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(c) The reaction of methylbenzene with thionyl bromide, $SOBr_2$, in the presence of an iron(III) bromide catalyst, $FeBr_3$, is shown in Fig. 5.2.

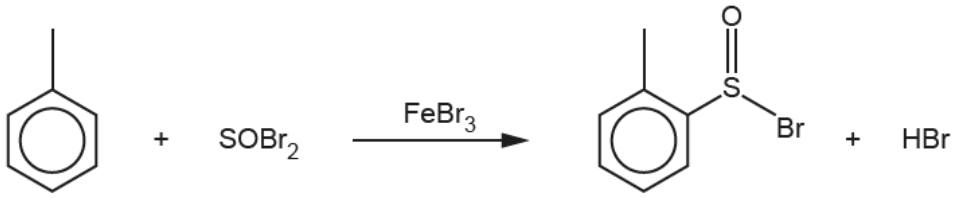


Fig. 5.2

The mechanism of this reaction is similar to that of the bromination of benzene.

The first step of the mechanism generates the $SOBr^+$ electrophile, as shown.

$$SOBr_2 + FeBr_3 \rightarrow SOBr^+ + FeBr_4^-$$

(i) The reaction of methylbenzene with $SOBr^+$ ions is shown in Fig. 5.3. Complete the mechanism in Fig. 5.3.

Include all relevant curly arrows and charges.

Draw the structure of the organic intermediate.

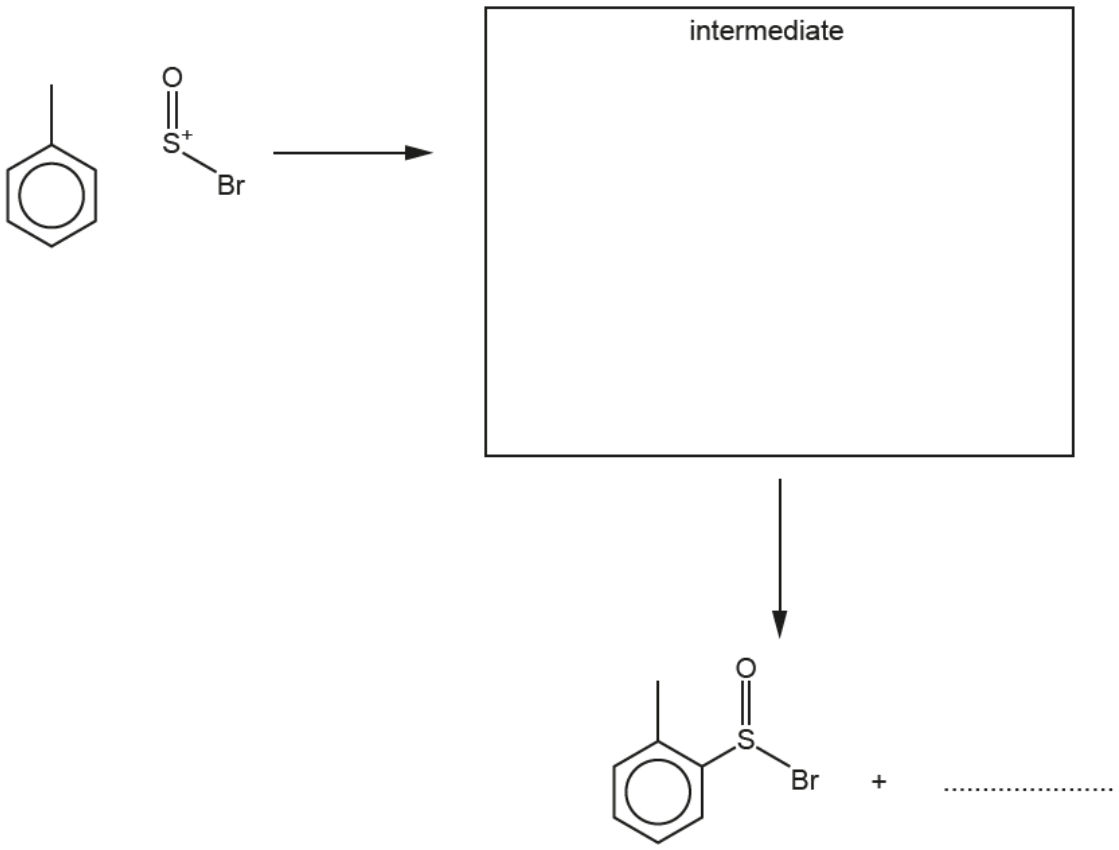


Fig. 5.3

[3]

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(ii) The reaction shown in Fig. 5.2 produces a small amount of a by-product, **P**, with the molecular formula $C_{14}H_{14}OS$.

Suggest a structure for by-product **P**.

[1]

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4. June/2023/Paper_9701/42/No.7(a _ c)

(a) Explain why phenol is brominated much more easily than benzene is brominated.

.....

.....

.....

.....

..... [3]

(b) Iodine monobromide, I–Br, reacts with benzene in the presence of an $AlBr_3$ catalyst.

Predict whether the organic product will be bromobenzene or iodobenzene.
Explain your answer.

.....

.....

..... [1]

(c) Fig. 7.1 shows some reactions of phenol.

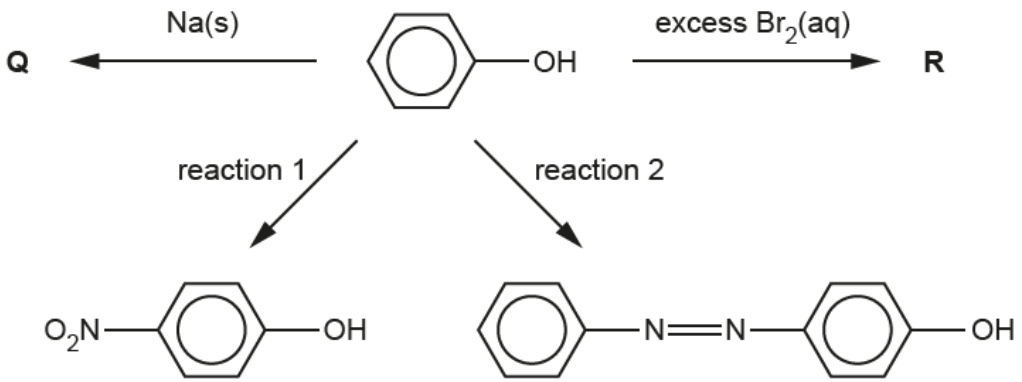


Fig. 7.1

(i) Give an equation for the reaction of phenol with Na(s).

..... [1]

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(ii) Draw the structure of the organic product, **R**, formed when phenol reacts with an excess of $Br_2(aq)$.

[1]

(iii) State the reagents and conditions for reaction 1 and reaction 2 in Fig. 7.1.

reaction 1 .....

reaction 2 .....

[2]

[Total: 8]

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5. March/2023/Paper_9701/42/No.5(a_ e)

Tulobuterol is used in some medicines.

tulobuterol

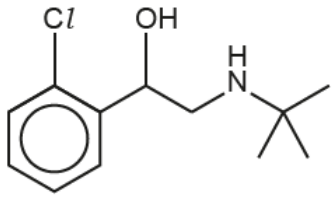


Fig. 5.1

(a) Tulobuterol contains a benzene ring in its structure.

Describe and explain the shape of benzene.

In your answer, include:

- the bond angle between carbon atoms
- the hybridisation of the carbon atoms
- how orbital overlap forms σ and π bonds between the carbon atoms.

.....

.....

.....

..... [3]

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(b) In a synthesis of tulobuterol, the first step involves the formation of chlorobenzene. Benzene reacts with Cl_2 in the presence of an $AlCl_3$ catalyst.



Fig. 5.2

(i) Write an equation to show how Cl_2 reacts with $AlCl_3$ to generate an electrophile.

..... [1]

(ii) Complete the mechanism in Fig. 5.3 for the reaction of benzene with the electrophile generated in **(b)(i)**.

Include all relevant curly arrows and charges.

Draw the structure of the intermediate.

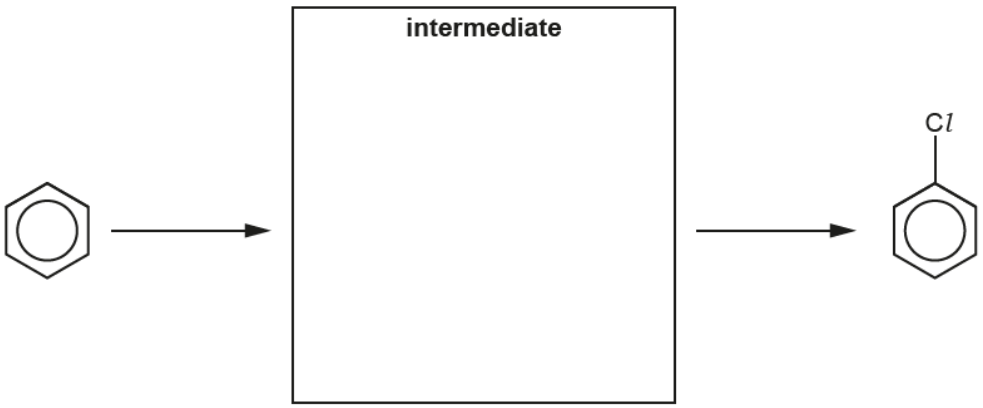


Fig. 5.3

[3]

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(c) The second step of the synthesis involves the reaction of chlorobenzene with $ClCOCH_2Cl$, also in the presence of an $AlCl_3$ catalyst, forming compound **Q**.

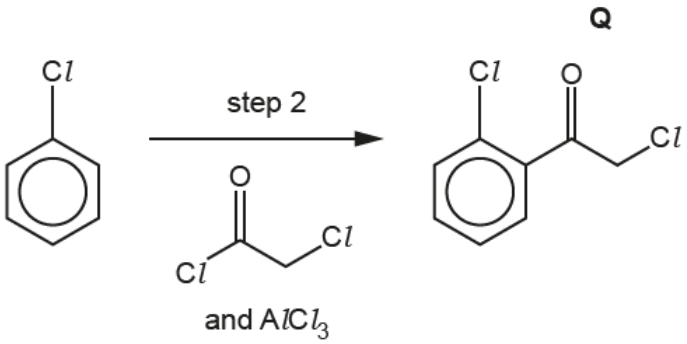


Fig. 5.4

(i) Name the mechanism of the reaction in step 2.

..... [1]

(ii) Draw the structure of an isomer of **Q** that forms as an organic by-product of the reaction in step 2.

[1]

(iii) The reactants used in step 2 contain acyl chloride, alkyl chloride and aryl chloride functional groups.

State and explain the relative ease of hydrolysis of acyl chlorides, alkyl chlorides and aryl chlorides.

..... , ... , ...
easiest to hydrolyse hardest to hydrolyse

.....

.....

.....

.....

..... [3]

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(d) Tulobuterol is produced from **Q** as shown in Fig. 5.5.

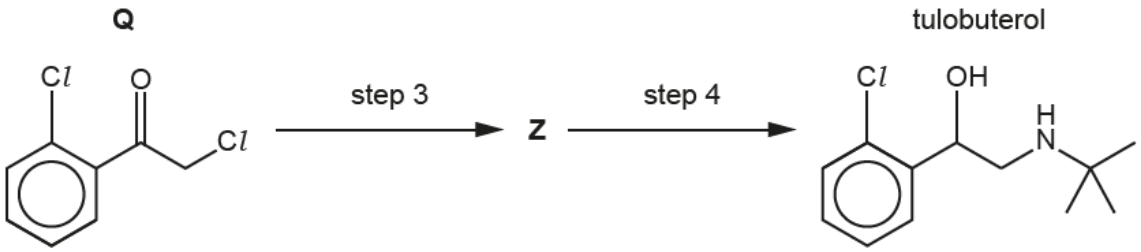


Fig. 5.5

Suggest reagents and conditions for steps 3 and 4.

Draw the structure of **Z** in the box.

step 3 .....

step 4 .....

Z

[3]

(e) The synthesis produces two enantiomers of tulobuterol.

(i) Define enantiomers.

.....

.....

..... [1]

(ii) Suggest **one** disadvantage of producing two enantiomers in this synthesis.

.....

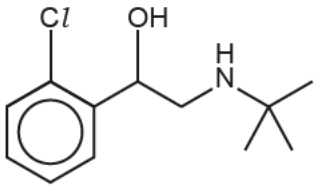
..... [1]

(iii) Suggest a method of adapting the synthesis to produce a single enantiomer.

..... [1]

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tulobuterol



(f) **(i)** Predict the number of peaks that would be seen in the carbon-13 NMR spectrum of tulobuterol.

..... [1]

(ii) The proton (^{1}H) NMR spectrum of tulobuterol dissolved in D_2O shows peaks in four different types of proton environment.

The peak for the —CH_2N— environment is a doublet in the chemical shift range δ = 2.0–3.0 ppm.

Give details for each of the other **three** peaks in the proton NMR spectrum of tulobuterol, to include:

- chemical shift
- environment of the proton
- splitting pattern
- number of ^{1}H atoms responsible.

Table 5.1 gives information about typical chemical shift values.

.....

.....

.....

.....

.....

.....

..... [3]

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Table 5.1

environment of proton	example	chemical shift range δ / ppm
alkane	–C**H**$_3$, –C**H**$_2$–, >C**H**–	0.9–1.7
alkyl next to C=O	C**H**$_3$–C=O, –C**H**$_2$–C=O, >C**H**–C=O	2.2–3.0
alkyl next to aromatic ring	C**H**$_3$–Ar, –C**H**$_2$–Ar, >C**H**–Ar	2.3–3.0
alkyl next to electronegative atom	C**H**$_3$–O, –C**H**$_2$–O, –C**H**$_2$–Cl	3.2–4.0
attached to alkene	=C**H**R	4.5–6.0
attached to aromatic ring	**H**–Ar	6.0–9.0
aldehyde	**H**COR	9.3–10.5
alcohol	RO**H**	0.5–6.0
phenol	Ar–O**H**	4.5–7.0
carboxylic acid	RCOO**H**	9.0–13.0
alkyl amine	R–N**H**–	1.0–5.0
aryl amine	Ar–N**H**$_2$	3.0–6.0
amide	RCON**H**R	5.0–12.0

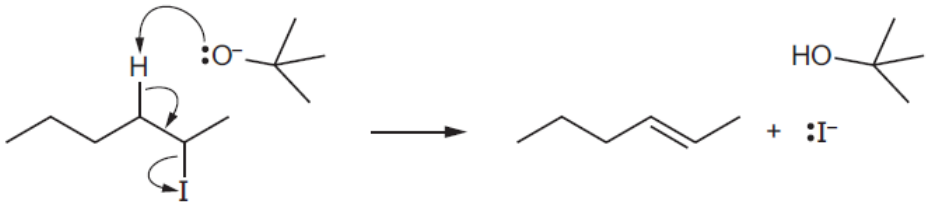
[Total: 22]

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Hydrocarbons – 2021 AS

1. Nov/2021/Paper_11/No.20

Hex-2-ene can be made by the reaction shown.



Which statement about this reaction is correct?

A $(CH_3)_3CO^-$ is behaving as a Brønsted-Lowry base.

B $(CH_3)_3CO^-$ is behaving as an oxidising agent.

C The C–I bond breaks via homolytic fission.

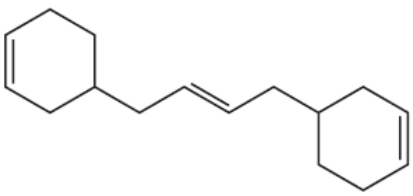
D This is a hydrolysis reaction.

2. Nov/2021/Paper_11/No.21

Structural isomerism **only** should be considered when answering this question.

Molecule X contains three C=C double bonds. One mole of X is reacted with three moles of HBr. The carbon skeleton is unchanged.

molecule X



How many different products are formed?

A 3 **B** 4 **C** 6 **D** 8

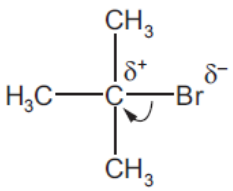
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3. Nov/2021/Paper_11/No.23

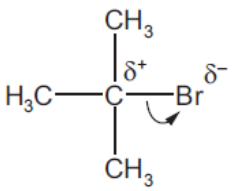
When 2-bromo-2-methylpropane reacts with aqueous sodium hydroxide, an alcohol is formed.

Which diagram describes the first step in the reaction mechanism?

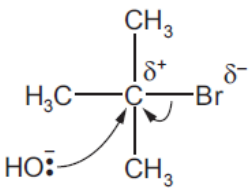
A



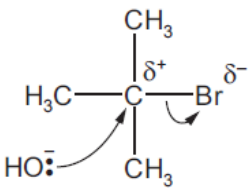
B



C



D



4. Nov/2021/Paper_11/No.38

One molecule of dodecane, $C_{12}H_{26}$, is cracked, producing three product molecules, X, Y and Z.

X is a straight chain alkane. Y and Z are straight chain alkenes with different M_r values.

Which statements about X, Y and Z are correct?

1 If Y and Z are but-1-ene and ethene respectively, X will be hexane.

2 If X is butane, then Y and Z could both show *cis-trans* isomerism.

3 X could be octane.

5. Nov/2021/Paper_11/No.39

Which statements about chlorofluoroalkanes are correct?

1 Both the C–C*l* and C–F bonds are readily dissociated by ultra-violet light.

2 They have caused ozone depletion.

3 They are relatively chemically inert.

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6. Nov/2021/Paper_11/No.40

Which reactions of propan-1-ol have water as one of the products?

1 passing propan-1-ol vapour over hot Al_2O_3

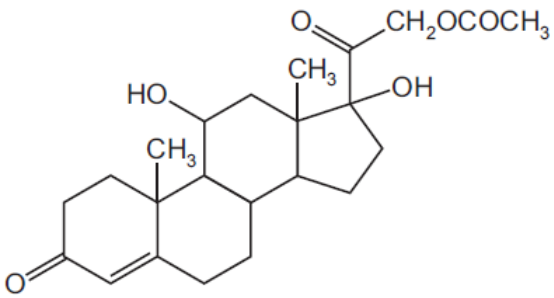
2 mixing propan-1-ol with warm ethanoic acid and a few drops of concentrated sulfuric acid

3 warming propan-1-ol with HBr

7. Nov/2021/Paper_12/No.20

The formula of hydrocortisone acetate is shown.

hydrocortisone acetate



Which row is correct?

	number of C atoms in one molecule	number of chiral atoms in one molecule
A	22	7
B	22	8
C	23	7
D	23	8

8. Nov/2021/Paper_12/No.22

Structural and stereoisomerism should be taken into account when answering this question.

Y is a gaseous hydrocarbon which decolourises aqueous bromine. It contains no rings.

10.0 g of Y occupies a volume of 3.43 dm^3 under room conditions.

How many isomeric structures are possible for Y?

A 4 **B** 5 **C** 6 **D** 7

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9. Nov/2021/Paper_12/No.23

Which equation represents a valid propagation step in the chlorination of ethane?

A $C_2H_5Cl + Cl\bullet \rightarrow C_2H_4Cl\bullet + HCl$

B $C_2H_6 + Cl\bullet \rightarrow C_2H_5Cl + H\bullet$

C $C_2H_5Cl + H\bullet \rightarrow C_2H_5\bullet + HCl$

D $C_2H_5\bullet + Cl\bullet \rightarrow C_2H_5Cl$

10. Nov/2021/Paper_12/No.37

What is the same for a pair of optical isomers?

1 their empirical formula

2 their functional groups

3 their structural formula

11. Nov/2021/Paper_12/No.38

Which of the molecular formulae represent at least one compound that can undergo addition polymerisation?

1 C_4H_8

2 C_2H_3Cl

3 C_3H_6O

12. Nov/2021/Paper_12/No.39

Which of the reactions give products containing a chiral centre?

1 $CH_2(OH)COCO_2H$ + an excess of HCN

2 $CH_2(OH)COCO_2H$ + an excess of $NaBH_4$

3 $CH_2(OH)COCO_2H$ + an excess of $LiAlH_4$

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13. Nov/2021/Paper_12/No.40

Ethyl butanoate is heated with a dilute aqueous solution of sodium hydroxide.

Which substances are products of this reaction?

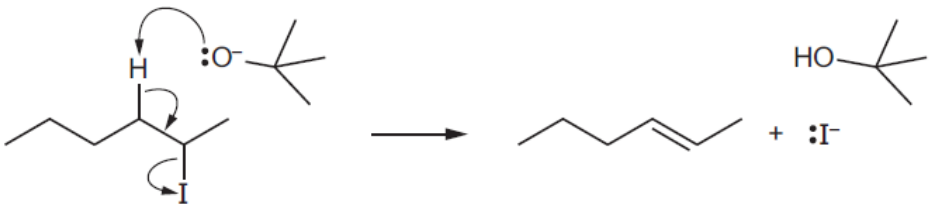
1 sodium butanoate

2 water

3 sodium ethanoate

14. Nov/2021/Paper_13/No.20

Hex-2-ene can be made by the reaction shown.



Which statement about this reaction is correct?

A $(CH_3)_3CO^-$ is behaving as a Brønsted-Lowry base.

B $(CH_3)_3CO^-$ is behaving as an oxidising agent.

C The C–I bond breaks via homolytic fission.

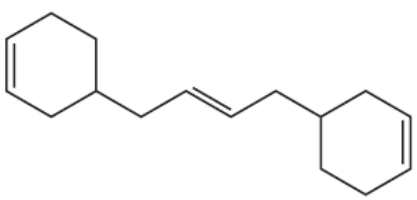
D This is a hydrolysis reaction.

15. Nov/2021/Paper_13/No.21

Structural isomerism **only** should be considered when answering this question.

Molecule X contains three C=C double bonds. One mole of X is reacted with three moles of HBr. The carbon skeleton is unchanged.

molecule X



How many different products are formed?

A 3 **B** 4 **C** 6 **D** 8

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16. Nov/2021/Paper_13/No.22

Structural isomerism **and** stereoisomerism should be considered when answering this question.

A colourless liquid, $C_5H_{11}Cl$, exists as a mixture of two optical isomers.

When heated with sodium hydroxide in ethanol, a mixture of **only two** alkenes is formed.

What could the colourless liquid be?

A $(CH_3CH_2)_2CHCl$

B $CH_3CH_2CH_2CHClCH_3$

C $CH_3CH_2CCl(CH_3)_2$

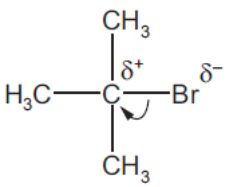
D $(CH_3)_2CHCHClCH_3$

17. Nov/2021/Paper_13/No.23

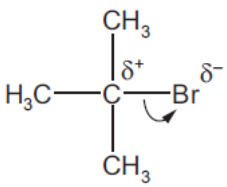
When 2-bromo-2-methylpropane reacts with aqueous sodium hydroxide, an alcohol is formed.

Which diagram describes the first step in the reaction mechanism?

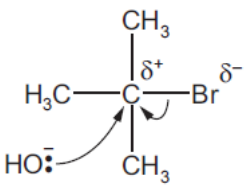
A



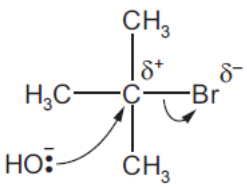
B



C



D



18. Nov/2021/Paper_13/No.24

When an organic compound, Q, is treated with phosphorus pentachloride, fumes of hydrogen chloride are evolved. When Q is warmed with acidified aqueous potassium dichromate(VI), the solution turns green.

What is Q?

A CH_3CH_2CHO

B $CH_3CH_2CO_2H$

C $CH_3CH(OH)CH_3$

D $(CH_3)_3COH$

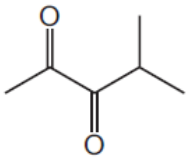
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19. Nov/2021/Paper_13/No.29

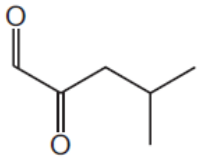
Reduction of compound R with $LiAlH_4$ gives the compound 4-methylpentane-2,3-diol.

What could be the identity of compound R?

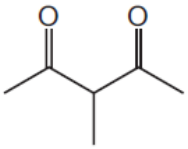
A



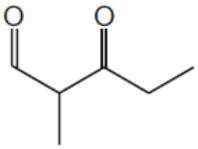
B



C



D



20. Nov/2021/Paper_13/No.38

One molecule of dodecane, $C_{12}H_{26}$, is cracked, producing three product molecules, X, Y and Z.

X is a straight chain alkane. Y and Z are straight chain alkenes with different M_r values.

Which statements about X, Y and Z are correct?

1 If Y and Z are but-1-ene and ethene respectively, X will be hexane.

2 If X is butane, then Y and Z could both show *cis-trans* isomerism.

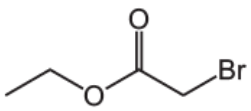
3 X could be octane.

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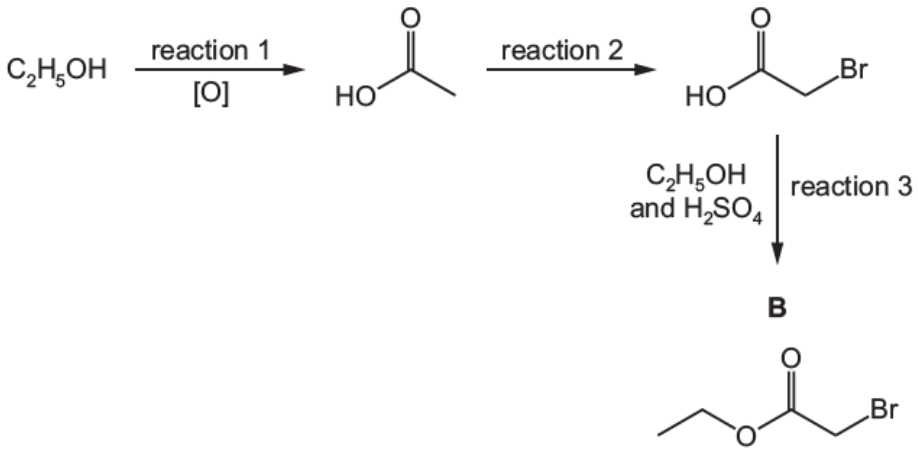
21. Nov/2021/Paper_21/No.4

Compound **B** is a liquid with a fruity smell.

B



The reaction scheme shows how **B** can be made from ethanol, C_2H_5OH.



(a) (i) Reaction 1 is an oxidation reaction.

Give the reagent(s) and conditions required for reaction 1.

reagent(s) .....

conditions .....

.....

[2]

(ii) Construct an equation to represent reaction 1.

Use [O] to represent an oxygen atom from the oxidising agent in this reaction.

..... [1]

(iii) Suggest the type of reaction that occurs in reaction 2.

..... [1]

(iv) H_2SO_4 acts as a homogeneous catalyst in reaction 3.

Explain why H_2SO_4 is described as *homogeneous*.

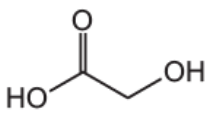
.....

..... [1]

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(b) Reaction 2 needs to take place in the absence of water to prevent formation of compound **C**.

C



If **C** is present in the reaction mixture of reaction 3, a different compound, compound **D**, will also form. Compound **D** has two identical functional groups.

The infrared spectrum of **D** shows strong absorptions at 1100 cm^{-1} and 1720 cm^{-1}, but no absorption due to O–H bonds.

Use the *Data Booklet* to identify the functional group present in **D**.

Explain your answer as fully as you can.

.....

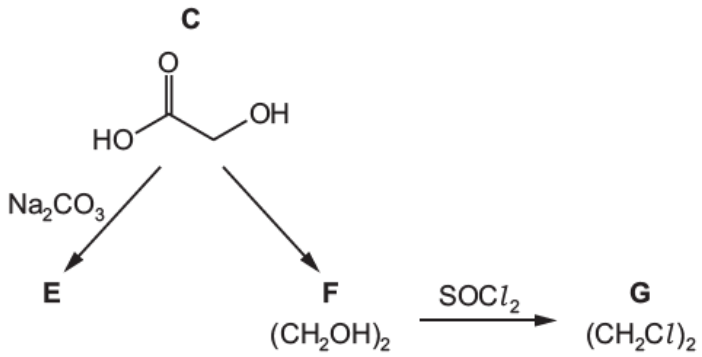
.....

.....

..... [3]

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(c) Some other reactions of **C** are shown.



(i) Draw the structure of **E**.

[1]

(ii) Suggest why $NaBH_4$ is not a suitable reagent to make **F**, $(CH_2OH)_2$, from **C**.
Explain your answer.

.....

..... [1]

(iii) Construct an equation for the reaction of $(CH_2OH)_2$ with $SOCl_2$ to form **G**, $(CH_2Cl)_2$.

..... [1]

(d) Explain why **C** is very soluble in water.

.....

.....

..... [1]

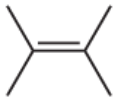
[Total: 12]

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22. Nov/2021/Paper_22/No.3

Compound **T** is an isomer of C_6H_{12}.

T



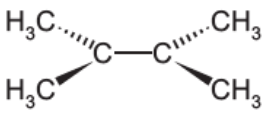
(a) Name **T**.

..... [1]

(b) Draw the skeletal formula of a structural isomer of **T** that shows *cis-trans* (geometrical) isomerism.

[1]

(c) Each carbon atom in **T** forms a sigma (σ) bond to at least one other carbon atom, as shown.

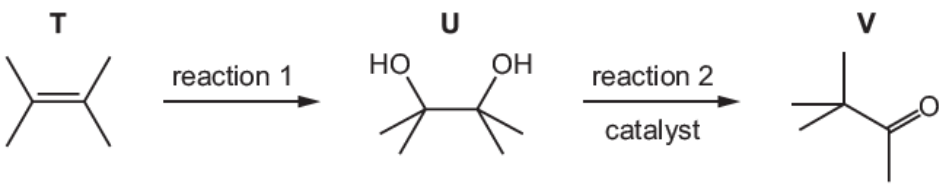


(i) On the diagram, draw the orbitals that represent the pi (π) bond that is also present in **T**. [1]

(ii) State the hybridisation of the two carbon atoms between which the pi (π) bond forms.

..... [1]

(d) A reaction scheme starting with **T** is shown. Reaction 2 occurs in the presence of a catalyst; knowledge of the mechanism for this reaction is not required.



(i) Give the reagent(s) and conditions for reaction 1.

..... [1]

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(ii) State and explain how 2,4-dinitrophenylhydrazine (2,4-DNPH) can be used to detect the presence of **V** as a product of reaction 2.

.....

.....

..... [2]

(iii) The progress of reaction 2 can be monitored by infrared spectroscopy.

The absorption caused by O–H bonds is always present because water is used as a solvent.

Identify two absorptions, and the bonds responsible for these absorptions, whose appearance will change significantly during the reaction.

1 .....

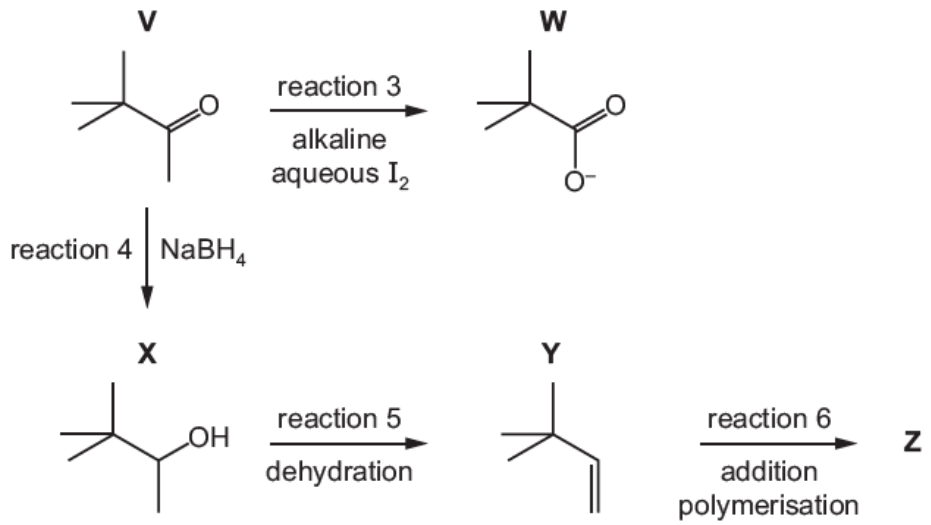
.....

2 .....

.....
[2]

(e) **V** is used in a wide range of organic reactions.

Some reactions of **V** are shown.



(i) **V** and **W** are colourless and soluble in water.

State what you would observe in reaction 3.

..... [1]

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(ii) Reaction 3 is a redox reaction.

Identify which of the **reactants** is reduced in this reaction.

..... [1]

(iii) Construct an equation for reaction 4.

Use [H] in the equation to represent an atom of hydrogen from $NaBH_4$.

$C_6H_{12}O$ + ... [1]

(iv) **X** is a mixture of two optical isomers.

Draw the two optical isomers in the boxes provided.

[2]

(v) Both optical isomers of **X** can be dehydrated to form a single product, **Y**.
Give the reagent(s) and conditions required for reaction 5.

..... [1]

(vi) **Y** can form an addition polymer **Z**.

Draw one repeat unit of **Z**.

[1]

(vii) Reaction 6 does not proceed quickly at room temperature.

Suggest why this is the case.

.....

..... [1]

[Total: 17]

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23. March/2021/Paper_12/No.19

Methylamine, CH_3NH_2, has similar chemical properties to ammonia, NH_3. Methylamine reacts with hydrogen chloride to form a white crystalline salt, methylammonium chloride.

$$CH_3NH_2 + HCl \rightarrow CH_3NH_3^+Cl^-$$

A sample of methylammonium chloride is heated with aqueous sodium hydroxide.

What are the products?

A ammonia, sodium chloride and water

B ammonia, sodium hydrogencarbonate and sodium chloride

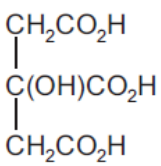
C methylamine, hydrogen chloride and water

D methylamine, sodium chloride and water

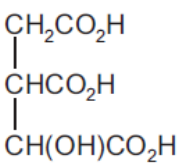
24. March/2021/Paper_12/No.20

The structures of citric acid and isocitric acid are shown.

citric acid



isocitric acid



How many chiral centres does each acid possess?

	citric acid	isocitric acid
A	1	1
B	1	2
C	0	1
D	0	2

25. March/2021/Paper_12/No.25

Dibromopentanes can undergo 'double elimination' reactions to produce hydrocarbons.

$$2NaOH + C_5H_{10}Br_2 \rightarrow C_5H_8 + 2NaBr + 2H_2O$$

Which isomer produces only one hydrocarbon product?

A 1,5-dibromopentane

B 1,4-dibromopentane

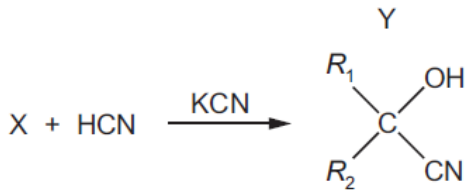
C 2,3-dibromopentane

D 2,4-dibromopentane

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26. March/2021/Paper_12/No.26

The diagram shows the formation of compound Y from compound X in a chemical reaction. R_1 and R_2 are alkyl groups.



Which row about this reaction is correct?

	mechanism	compound X
A	electrophilic addition	aldehyde
B	electrophilic addition	ketone
C	nucleophilic addition	ketone
D	nucleophilic addition	aldehyde

27. March/2021/Paper_12/No.37

In which reactions is the major product formed by a nucleophilic substitution reaction?

1 bromoethane + potassium cyanide in ethanol

2 bromoethane + ammonia in ethanol under pressure

3 bromoethane + hot concentrated sodium hydroxide in ethanol

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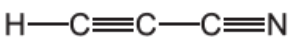
28. March/2021/Paper_22/No.3

Compounds **P**, **Q** and **R** have all been found in the atmosphere of one of Saturn's moons.

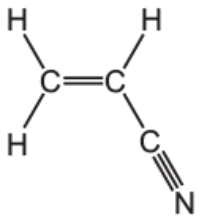
P



Q



R



(a) The equation for the complete combustion of **P**, $C_4N_2(l)$, is shown.

$$C_4N_2(l) + 4O_2(g) \rightarrow 4CO_2(g) + N_2(g) \qquad \Delta H = -2036\,kJ\,mol^{-1}$$

(i) The enthalpy change of formation, ΔH_f, of $CO_2(g)$ is $-384\,kJ\,mol^{-1}$.

Calculate the enthalpy change of formation, ΔH_f, of **P**, in $kJ\,mol^{-1}$.

ΔH_f of **P** = ... $kJ\,mol^{-1}$ [2]

(ii) One of the products of the complete combustion of **P** is nitrogen gas, $N_2(g)$.

Explain the lack of reactivity of nitrogen.

..... [1]

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(b) **Q** forms when HCN reacts with ethyne, H—C≡C—H.

(i) Ethyne, HCN and **Q** are all weak Brønsted–Lowry acids.

Explain what is meant by the term *weak Brønsted–Lowry acid*.

.....

.....

..... [2]

(ii) Ethyne, HCN and **Q** all contain triple bonds between two atoms.

A triple bond consists of one sigma (σ) and two pi (π) bonds.

Draw a labelled diagram to show the formation of one pi (π) bond.

[2]

(c) **P** and **Q** can be detected in the atmosphere by infrared spectroscopy.

Identify **two** absorptions, and the bonds that correspond to these absorptions, that will appear in the infrared spectra of both **P** and **Q**.

1 .....

.....

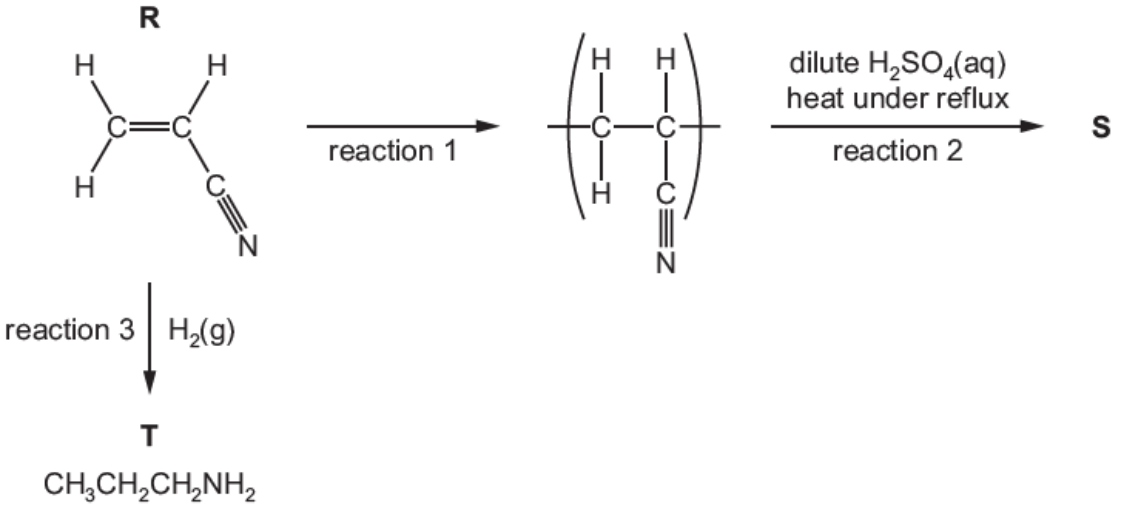
2 .....

.....

[2]

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(d) The flow chart shows some reactions of **R**.



(i) Name the type of reaction shown in reaction 1.

..... [1]

(ii) Draw the structure of **S**, the organic product of reaction 2.

[1]

(iii) Name **T**.

..... [1]

(iv) **T** can also be formed by the reaction of $CH_3CH_2CH_2Br$ with ammonia.

State the necessary conditions of this reaction.

..... [1]

[Total: 13]

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29. June/2021/Paper_11/No.20

Bromoethane reacts with cyanide ions, producing propanenitrile.

Which statement about the S_N2 mechanism of this reaction is correct?

A The lone pair of electrons on C of CN^- attacks the carbon atom of the C–Br bond.

B The lone pair of electrons on C of CN^- attacks the carbocation formed when the C–Br bond breaks.

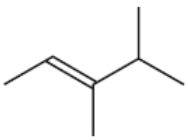
C The lone pair of electrons on N of CN^- attacks the carbon atom of the C–Br bond.

D The lone pair of electrons on N of CN^- attacks the carbocation formed when the C–Br bond breaks.

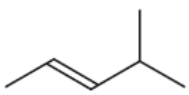
30. June/2021/Paper_11/No.21

Which compound would produce two different carboxylic acids when treated with hot, concentrated, acidified manganate(VII) ions?

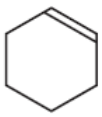
A



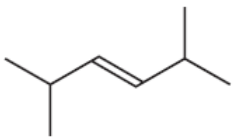
B



C



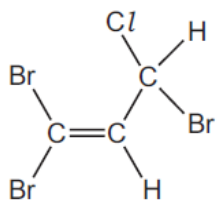
D



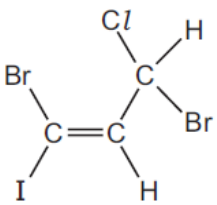
31. June/2021/Paper_11/No.22

Which compound could show **both** *cis-trans* isomerism and optical isomerism?

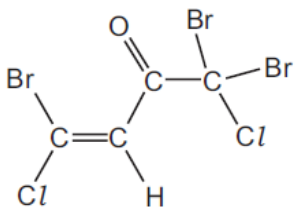
A



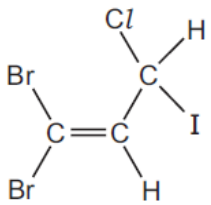
B



C



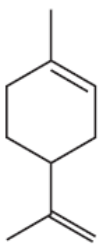
D



32. June/2021/Paper_11/No.23

Limonene is a hydrocarbon found in the rind of citrus fruits.

limonene



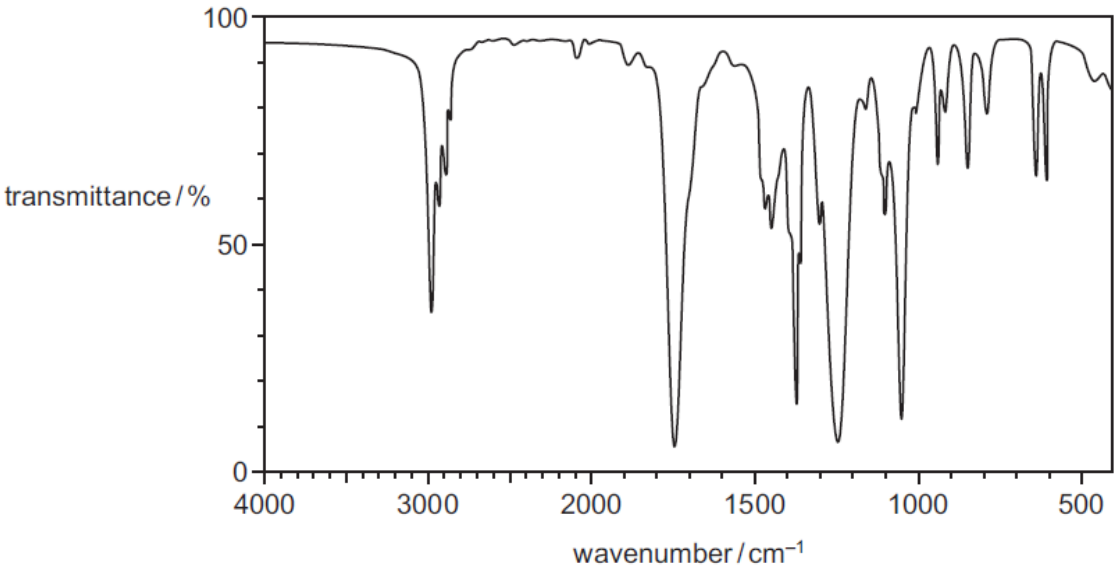
What is the molecular formula of limonene?

A $C_{10}H_{12}$ **B** $C_{10}H_{14}$ **C** $C_{10}H_{16}$ **D** $C_{10}H_{18}$

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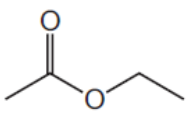
33. June/2021/Paper_11/No.26

Compound X has the empirical formula C_2H_4O. Its infra-red spectrum is shown.

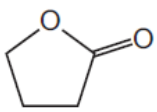


What could be the skeletal formula of compound X?

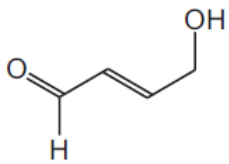
A



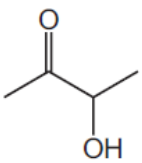
B



C



D



34. June/2021/Paper_11/No.29

The table describes four reactions of propene.

Which row is correct?

	reagent used	name of main organic product
A	aqueous bromine	2-bromopropane
B	cold acidified aqueous potassium manganate(VII)	propane-1,3-diol
C	hydrogen chloride	2-chloropropane
D	steam	propan-1-ol

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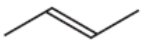
35. June/2021/Paper_11/No.33

A gaseous hydrocarbon has a density of 2.42 g dm^{-3} under room conditions.

What could be the skeletal formula of this hydrocarbon?

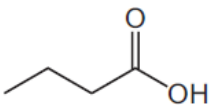
1 

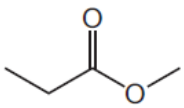
2 

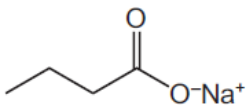
3 

36. June/2021/Paper_12/No.3

The structures represent three compounds, each with four carbon atoms per molecule.

X 

Y 

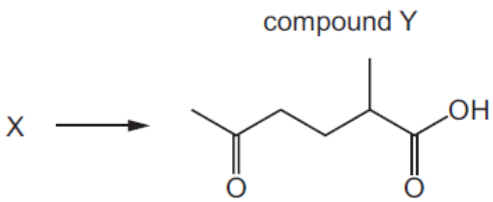
Z 

Which row is correct?

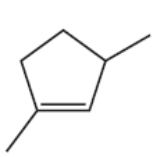
	lowest boiling point	→	highest boiling point
A	X	Y	Z
B	Y	X	Z
C	Z	X	Y
D	Z	Y	X

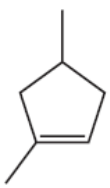
37. June/2021/Paper_12/No.22

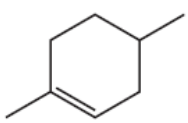
Compound X can be converted into compound Y in a single step.

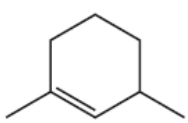


What could be the identity of X?

A 

B 

C 

D 

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38. June/2021/Paper_12/No.23

Methane and bromine react by free radical substitution.

P and Q are involved in the reaction mechanism.

P and Q:

- are **both** involved in propagation steps as reactants
- are **both** involved in termination steps as reactants.

What could be P and Q?

A Br and H **B** Br and CH_3 **C** Br and C_2H_6 **D** CH_3 and CH_3Br

39. June/2021/Paper_12/No.24

A few drops of 2-bromopropane were placed in a test-tube. An equal volume of aqueous silver nitrate was added. A precipitate was formed.

The experiment was repeated with 2-iodopropane.

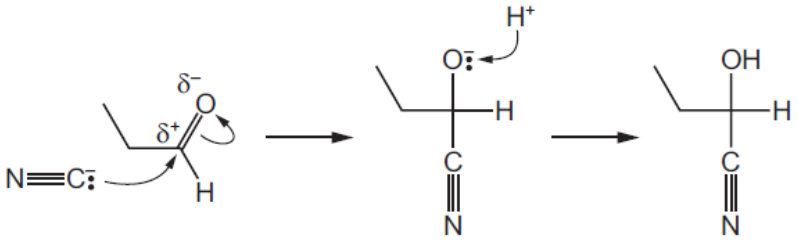
Which row is correct?

	colour of precipitate from **2-bromopropane** + $AgNO_3(aq)$	faster rate of reaction
A	cream	2-bromopropane + $AgNO_3(aq)$
B	yellow	2-bromopropane + $AgNO_3(aq)$
C	cream	2-iodopropane + $AgNO_3(aq)$
D	yellow	2-iodopropane + $AgNO_3(aq)$

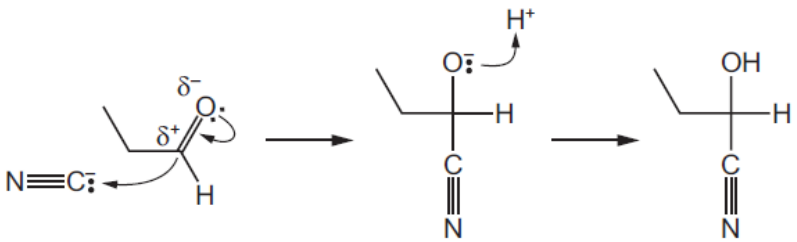
40. June/2021/Paper_12/No.28

Which reaction mechanism for the formation of $C_2H_5CH(OH)(CN)$ is correct?

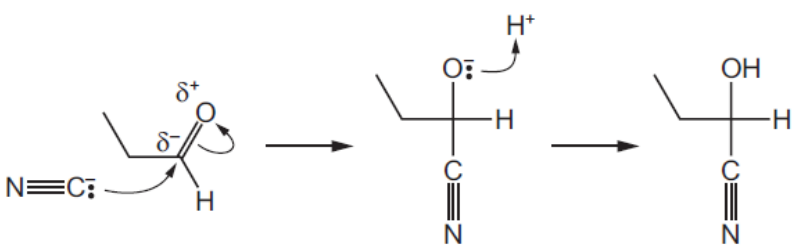
A



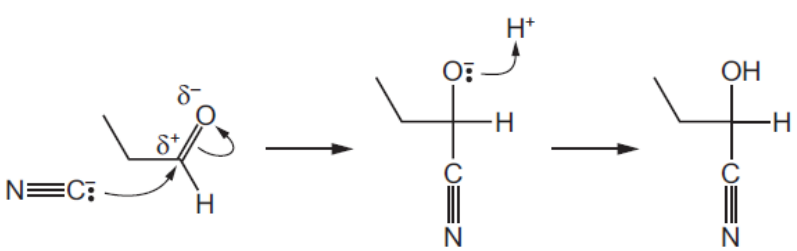
B



C



D



41. June/2021/Paper_12/No.32

Compound X is a straight chain hydrocarbon with an M_r of 84.

What can be determined about X?

1 empirical formula

2 molecular formula

3 whether X contains a C=C bond or not

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The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

42. June/2021/Paper_13/No.20

Which compound shows stereoisomerism?

A 2-methylbut-2-ene

B 2-chloropropan-1-ol

C difluorochlorobromomethane

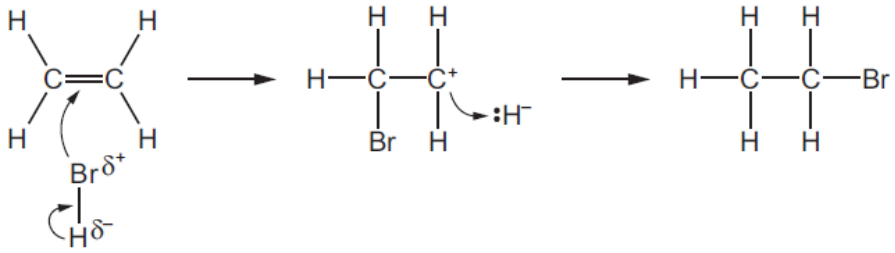
D pent-1-ene

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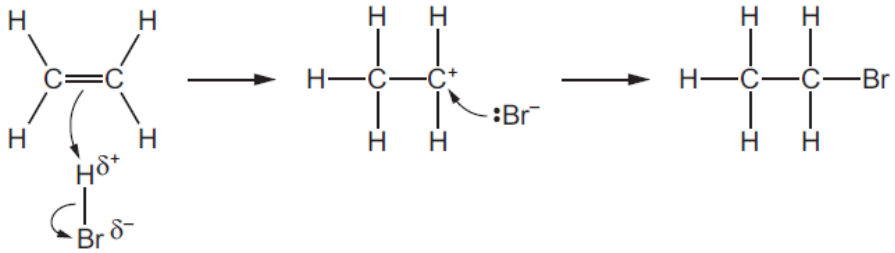
43. June/2021/Paper_13/No.22

What is the correct mechanism for the addition of hydrogen bromide to ethene?

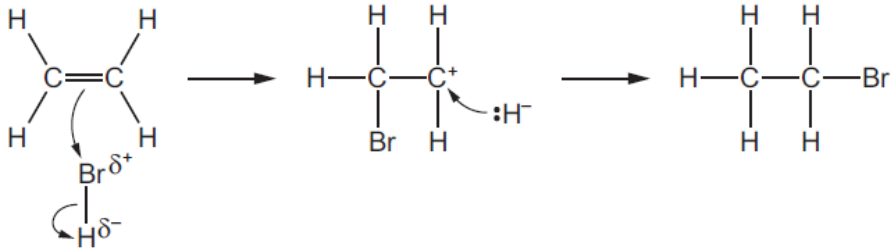
A



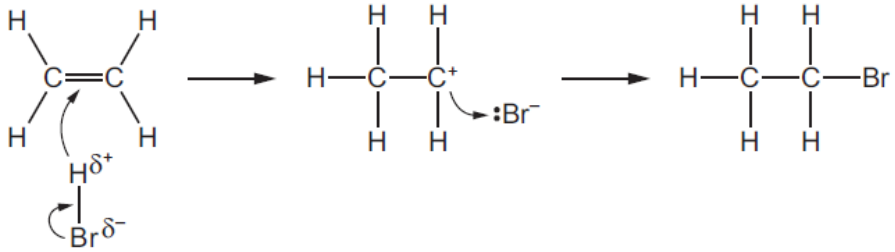
B



C



D



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44. June/2021/Paper_21/No.5

(a) Naphtha is a mixture which contains only hydrocarbon molecules.

(i) What is meant by the term *hydrocarbon*?

.....

..... [1]

(ii) Name the raw material that is used to produce a sample of naphtha.

..... [1]

(b) Compound **V** is found in naphtha. It has a molecular formula $C_{10}H_{22}$.

When **V** is heated at high pressure in the absence of air, an equal number of moles of ethene, propene and **W** are made. **W** is a compound made of straight chain, saturated molecules.

(i) Name the process that describes this reaction.

..... [1]

(ii) Deduce the structure of **W**. Draw its structure below.

[1]

(c) Propene is separated from the mixture and heated in air in the presence of a catalyst. Propene is oxidised to **X**, which contains two functional groups.

(i) Effervescence is seen when $Na_2CO_3(aq)$ is added to **X**.

Identify the functional group present in **X** which is responsible for this observation.

..... [1]

(ii) Identify a reagent which could be used to show that **X** contains a C=C. Include relevant observations.

.....

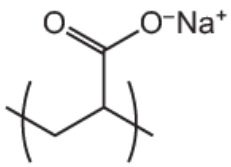
..... [2]

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(d) **X** reacts with another reagent to form **Y**.

Molecules of **Y** react together to form addition polymer **Z**. The diagram shows the repeat unit of polymer **Z**.

repeat unit of polymer **Z**



Draw the structural formula of monomer **Y**.

[1]

(e) Polymer **Z** is useful because it absorbs large amounts of water. However, there are problems associated with the disposal of products containing polymer **Z**.

Combustion is not an appropriate method to dispose of pure **Z** because the process releases harmful gases. Some of these gases contribute to the enhanced greenhouse effect.

(i) Identify a gas released during the combustion of **Z** which contributes to the enhanced greenhouse effect.

..... [1]

(ii) Identify another gas which could be produced during the combustion of pure **Z**. Describe a consequence, other than the enhanced greenhouse effect, of its release into the atmosphere.

gas .....

consequence .....

[1]

[Total: 10]

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45. June/2021/Paper_21/No.6

Propene, C_3H_6, reacts with H_2O in the presence of an acid catalyst to form an alcohol with molecular formula C_3H_8O.

(a) Name this type of reaction.

..... [1]

(b) Name the catalyst used and state the conditions needed for this reaction to occur.

catalyst .....

conditions .....

[2]

(c) Complete the table to show the numbers of sigma (σ) bonds and pi (π) bonds present in propene, C_3H_6, and C_3H_8O.

	σ	π
C_3H_6		
C_3H_8O		

[2]

(d) The reaction of propene, C_3H_6, with H_2O occurs in a two-step mechanism. In step 1 C_3H_6 reacts with the catalyst, H^+, to form a carbocation.

(i) Draw structures to identify the more stable and less stable carbocations which can form in step 1. Explain your answer.

more stable carbocation	**less** stable carbocation

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explanation .....

.....

.....

.....

.....

[3]

(ii) Name the major organic product formed from the reaction of propene, C_3H_6, with H_2O.

..... [1]

(e) 2-bromopropane reacts to form propene, hydrogen bromide and water under certain conditions.

(i) Name this type of reaction.

..... [1]

(ii) Describe the reagents and conditions needed to favour this reaction.

reagents .....

conditions .....

[2]

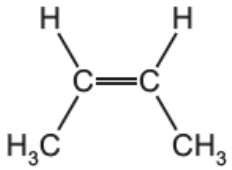
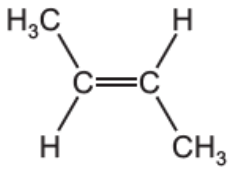
[Total: 12]

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46. June/2021/Paper_22/No.4

(a) The table shows the structural formulae of four compounds, **A**, **B**, **C** and **D**, with molecular formula C_4H_8.

(i) Complete the table by giving the systematic name of **A**, **B**, **C** and **D**.

	structural formula	name
A	$CH_3CH_2CH{=}CH_2$	
B		
C		
D	$CH_2{=}C(CH_3)_2$	

[4]

(ii) Explain what is meant by *stereoisomerism*.

.....

..... [1]

(b) **W** is an alkene with formula C_4H_8. It reacts with HBr to form two possible carbocations, $CH_3C^+(H)(CH_2CH_3)$ and $H_2C^+CH_2CH_2CH_3$.

(i) Identify **W** as compound **A**, **B**, **C** or **D**.

..... [1]

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(ii) Draw the skeletal formula of the major organic product formed when HBr reacts with **W**. Explain why this is the major organic product.

.....

.....

.....

[3]

(c) A sample of propan-1-ol reacts with concentrated sulfuric acid to form propene.

Identify the role of concentrated sulfuric acid in this reaction.

..... [1]

(d) Alcohol **Y** reacts completely when warmed with acidified $Cr_2O_7^{2-}$ to form **Z**.

Z is distilled from the reaction mixture as soon as it is made.

Tollens' reagent is added to a sample of **Z** and warmed. A silver mirror forms.

(i) Name the type of reaction that occurs when **Y** reacts to form **Z**.

..... [1]

(ii) Identify with a tick (✓) the functional group(s) present in **Z**.

functional group	present in **Z**
aldehyde	
ketone	
carboxylic acid	

[1]

[Total: 12]

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1. June/2022/Paper_11/No.30

Oct-1-ene, $CH_3(CH_2)_5CH=CH_2$, can be thermally cracked.

Which of the compounds W, X, Y and Z can be obtained by thermally cracking oct-1-ene?

W	X	Y	Z
$CH_2=CH_2$	$CH_3CH=CH_2$	$CH_3CH_2CH_3$	$CH_2=CHCH=CH_2$

A W, X, Y and Z

B W, X and Y only

C W, X and Z only

D W and X only

2. June/2022/Paper_12/No.5

Ethane and ethene are both hydrocarbon molecules.

What is a feature of **both** molecules?

A a planar structure

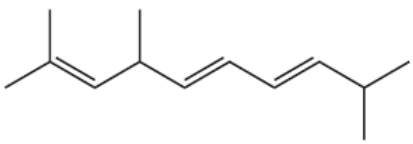
B bond angles of 109°

C σ covalent bonds

D π covalent bonds

3. June/2022/Paper_12/No.26

A skeletal formula is shown.



What is the total number of stereoisomers including the one shown?

A 4 **B** 6 **C** 8 **D** 16

4. June/2022/Paper_12/No.27

The molecular formula CH_3 can represent an anion, a cation or a free radical. Species with the molecular formula CH_3 can act as an electrophile, a free radical or a nucleophile depending on the number of outer shell electrons on the central carbon atom.

How many outer shell electrons on the central carbon atom must be present for CH_3 to act in these different ways?

	CH_3 as an electrophile	CH_3 as a free radical	CH_3 as a nucleophile
A	6	7	8
B	6	8	7
C	7	6	8
D	8	7	6

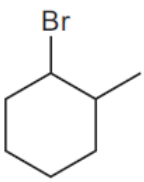
5. June/2022/Paper_12/No.28

Compound Z, $C_7H_{13}Br$, has two chiral centres. A sample of Z contains all four possible optical isomers.

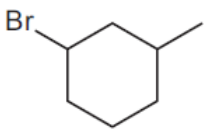
This sample of Z reacts with hot ethanolic NaOH to produce a mixture of **only** three isomers. Two of these isomers are optical isomers of each other.

What could be the formula of Z?

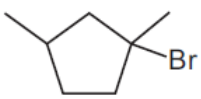
A



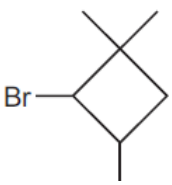
B



C



D



6. June/2022/Paper_12/No.29

The free-radical substitution reaction between methane and chlorine involves initiation, propagation and termination stages.

Which row is correct?

	involved in initiation stage	radical produced in a propagation stage
A	homolytic fission	H•
B	homolytic fission	CH_3•
C	heterolytic fission	H•
D	heterolytic fission	CH_3•

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7. June/2022/Paper_13/No.29

Structural isomerism and stereoisomerism should be considered when answering this question.

Y is a gaseous hydrocarbon which decolourises aqueous bromine.

10.0 g of Y occupies a volume of 3.43 dm^3 under room conditions.

How many isomeric structures are possible for Y?

A 4 **B** 5 **C** 6 **D** 7

8. June/2022/Paper_21/No.3(a, b)

Liquids that contain molecules of **T** smell like lemons.

T

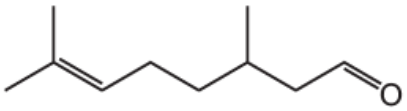


Fig. 3.1

(a) Molecules of **T** exist as a pair of stereoisomers.

Name the type of stereoisomerism shown by molecules of **T**. Explain your answer.

.....

..... [2]

(b) Two organic products are produced when a sample of **T** is heated under reflux with excess acidified concentrated $KMnO_4$.

Draw the structure of the two organic products, from this reaction, in the boxes.

organic product 1

organic product 2

[2]

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9. June/2022/Paper_21/No.4(b)

(b) **V** contains two types of functional group: a carboxylic acid and an alkene.

(i) Describe a chemical test and observation which confirms the presence of a carboxyl functional group.

.....

..... [2]

(ii) A 3.196 g sample of Br_2 reacts completely with 2.800 g of **V**.

Calculate how many alkene functional groups are present in one molecule of **V**. Show your working.

number of alkene functional groups in **V** = ... [1]

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10. June/2022/Paper_22/No.4(a)

(a) Bromine reacts with butane in the presence of ultraviolet light to form bromobutane.

Two structural isomers with the molecular formula C_4H_9Br are produced during this reaction.

(i) Draw the two structural isomers and state the systematic name of each isomer.

structural isomer **1**	structural isomer **2**
name	name .....

[2]

(ii) Identify the type of structural isomerism shown in **(a)(i)**.

..... [1]

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11. June/2022/Paper_22/No.6(a, b)

Z is a molecule which contains the elements carbon, hydrogen and oxygen only.

Z contains only alkene and carboxyl functional groups.

(a) Complete Table 6.1 by describing the observations that occur when two different reagents are added to separate samples of **Z**(aq).

Table 6.1

reagent added to **Z**(aq)	observation
$Br_2(aq)$	
$Na_2CO_3(s)$	

[2]

(b) Table 6.2 shows the percentage by mass of each element present in **Z**.

Table 6.2

element	percentage by mass / %
carbon	41.38
hydrogen	3.45
oxygen	55.17

Using the data in Table 6.2, demonstrate that the empirical formula of **Z** is CHO.
Show your working.

[1]

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1. Nov/2022/Paper_11/No.5

How many σ bonds are present in one $H–C{\equiv}C–C(CH_3)=CH(CH_3)$ molecule?

A 5 **B** 11 **C** 13 **D** 16

2. Nov/2022/Paper_11/No.35

Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomeric compounds with molecular formula $C_5H_6O_4$ contain two $–CO_2H$ groups and one C=C double bond?

A 5 **B** 6 **C** 7 **D** 8

3. Nov/2022/Paper_12/No.28

Which pair includes a hydrocarbon without a chiral centre?

A $CH_3CH_2CH_2CH(CH_3)CH_2CH_3$ $CH_3CH(CH_3)CH(CH_3)CH_2CH_3$

B $CH_3CH_2CH_2CH(CH_2CH_3)CH_3$ $CH_3CH_2CH_2CH(CH_3)CH_2CH_3$

C $CH_3CH_2CH_2CH(CH_3)CH_2CH_3$ $CH_3CH_2CH(CH_3)CH(CH_3)_2$

D $CH_3CH(CH_2CH_3)CH(CH_3)CH_3$ $CH_3CH(CH_3)CH_2CH(CH_3)_2$

4. Nov/2022/Paper_12/No.30

cis-but-2-ene reacts with cold dilute acidified potassium manganate(VII) solution to give product X.

cis-but-2-ene reacts with hot concentrated acidified potassium manganate(VII) solution to give product Y.

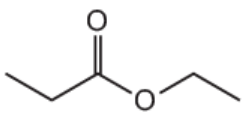
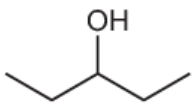
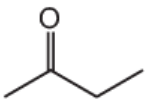
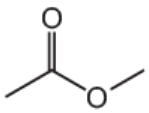
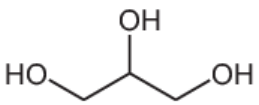
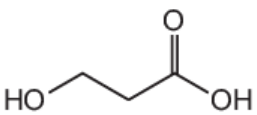
Which row describing the reactions of X and Y is correct?

	when sodium metal is added to separate samples of X and Y	when sodium hydroxide solution is added to separate samples of X and Y
A	both X and Y will react	neither X nor Y will react
B	both X and Y will react	only one of X and Y will react
C	only one of X and Y will react	neither X nor Y will react
D	only one of X and Y will react	only one of X and Y will react

5. Nov/2022/Paper_21/No.4

Organic compounds can be distinguished using chemical tests.
Table 4.1 shows four pairs of compounds.

Table 4.1

organic compounds		reagent	positive result of chemical test on identified compound
A1 	**A2** 		
B1 	**B2** 		
C1 	**C2** 		
D1 	**D2** 		

(a) Complete Table 4.1 to:

- identify a reagent that could distinguish between the compounds in each pair
- give the **positive** result of the chemical test **and** identify which compound shows this result.

Use a different reagent for each test. [8]

(b) **C1** has melting point –94 °C and boiling point +49 °C.

Explain these properties by referring to the type of van der Waals' forces between molecules.

.....

.....

..... [2]

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(c) Draw the structure of the cis isomer of **C2**.

[1]

(d) **C2** forms a polymer when heated gently.

(i) Identify the type of polymer that forms from **C2**.

..... [1]

(ii) Draw one repeat unit of the polymer formed from **C2**.

[2]

[Total: 14]

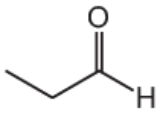
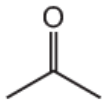
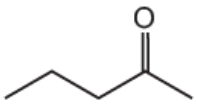
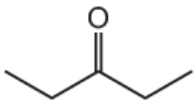
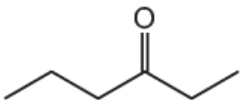
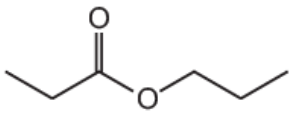
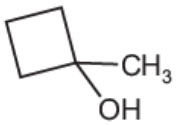
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6. Nov/2022/Paper_22/No.3(a, b)

Organic compounds can be distinguished using chemical tests and analytical techniques.

(a) Table 3.1 shows four pairs of organic compounds.

Table 3.1

organic compounds		reagent	positive result of chemical test on identified compound
A1 	**A2** 		
B1 	**B2** 		
C1 	**C2** 		
D1 	**D2** 		

(i) Complete Table 3.1 to:

- identify a reagent which can distinguish between the compounds in each pair
- give the **positive** result of the chemical test **and** identify which compound shows this result.

Use a different reagent for each test. [8]

(ii) **A1** and **A2** are structural isomers.

Define structural isomers.

.....

..... [1]

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(iii) Give the systematic name of **B2**.

..... [1]

(iv) Deduce the molecular formula of **D1**.

..... [1]

(b) **D2** forms polymer **Z** when heated gently.

(i) Identify the type of polymer that forms from **D2**.

..... [1]

(ii) Draw one repeat unit of polymer **Z**.

[2]

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Table 3.2

bond	functional group containing the bond	characteristic infrared absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–3100
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

Both spectra show absorptions between 2850 and 2950 cm^{-1} owing to C–H bonds in each molecule.

(i) Use the two infrared spectra and Table 3.2 to identify the functional group present only in **E**.
Explain your answer, referring only to absorptions at frequencies greater than 1500 cm^{-1}.

functional group .....

explanation .....

.....

[1]

(ii) Use the infrared spectrum of **F** to identify the functional group formed when **E** reacts with cold dilute acidified $KMnO_4(aq)$.
Explain your answer, referring only to absorptions at frequencies greater than 1500 cm^{-1}.

functional group .....

explanation .....

.....

[1]

(iii) The mass spectrum of **E** shows a molecular ion peak and an M+2 peak of approximately equal abundance at m/e = 120 and 122.

Deduce the relative molecular mass, M_r, of **E**.

M_r = ... [1]

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1. Nov/2023/Paper_ 9701/11/No.28

The hydrocarbon $C_{17}H_{36}$ can be cracked.

Which compound is the **least** likely to be produced in this reaction?

A C_3H_8 **B** C_4H_8 **C** C_8H_{16} **D** $C_{16}H_{34}$

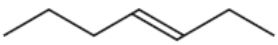
2. Nov/2023/Paper_ 9701/11/No.29

Which compound has an M_r of 84 and will react with HBr to give a product with an M_r of 164.9?

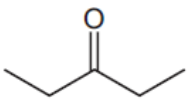
A



B



C



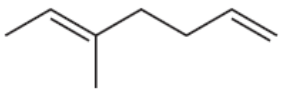
D



3. Nov/2023/Paper_ 9701/12/No.30

The structure of compound X is shown.

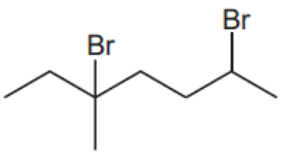
compound X



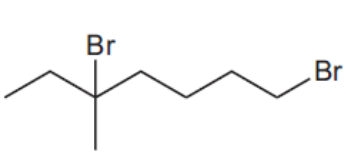
One mole of compound X reacts completely with two moles of hydrogen bromide.

What is the structure of the major product of this reaction?

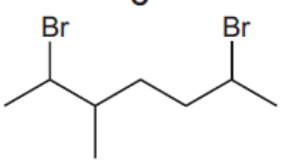
A



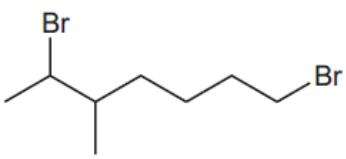
B



C



D



4. Nov/2023/Paper_ 9701/12/No.31

The formulae of three compounds are shown.

C_3H_7CHO $C_2H_5COCH_3$ $CH_2CHCH_2CH_2OH$

Only one of these compounds will decolourise bromine water. Only one of these compounds will produce a silver mirror with Tollens' reagent.

Which row shows the correct results?

	decolourises bromine water	forms a silver mirror with Tollens' reagent
A	C_3H_7CHO	$C_2H_5COCH_3$
B	$C_2H_5COCH_3$	C_3H_7CHO
C	$CH_2CHCH_2CH_2OH$	$C_2H_5COCH_3$
D	$CH_2CHCH_2CH_2OH$	C_3H_7CHO

5. Nov/2023/Paper_ 9701/12/No.32

Which list contains a compound that is **not** made during the free radical substitution of methane with chlorine?

A CH_3Cl, CCl_4, C_2H_6

B Cl_2, CH_2Cl_2, CCl_4

C CH_3Cl, CH_2Cl_2, $CHCl_3$

D CH_3Cl, $CHCl_3$, $C_2H_2Cl_2$

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6. Nov/2023/Paper_ 9701/21/No.4(a)

Compounds **C** and **D** are alkenes with the same molecular formula, C_5H_{10}.



Fig. 4.1

(a) (i) Give the systematic name of **D**.

..... [1]

(ii) Explain why **C** and **D** do not show geometrical (*cis/trans*) isomerism.

.....

..... [1]

(iii) Draw the structure of a molecule that is a positional isomer of **C** and **D**.

[1]

(iv) Give the structural formula of the compound formed when **D** reacts with $H_2(g)$ in the presence of a Pt catalyst.

..... [1]

(v) **C** can form an addition polymer.

Draw the structure of **one** repeat unit of this addition polymer.

[1]

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7. Nov/2023/Paper_ 9701/22/No.3(c)

(c) Fig. 3.1 shows a reaction scheme that involves H_3PO_4 in several reactions.

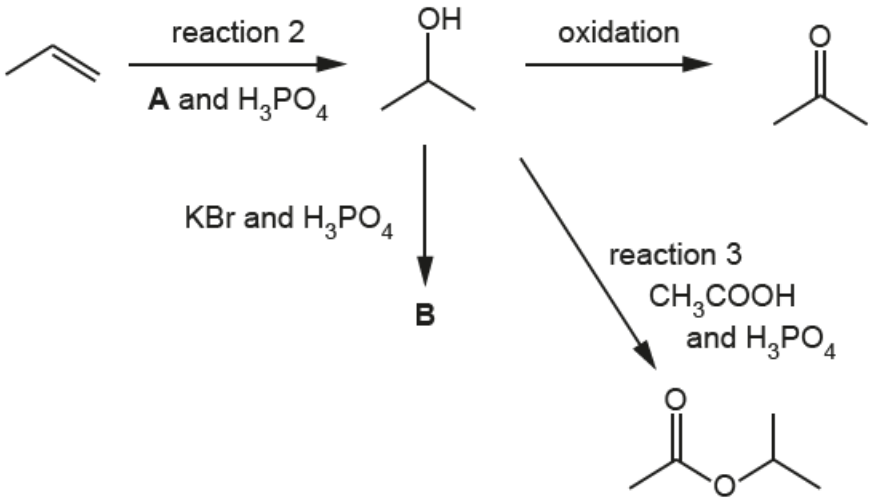


Fig. 3.1

(i) Identify **A**, which reacts with propene in the presence of H_3PO_4 in reaction 2.

..... [1]

(ii) Draw the structure of **B**.

[1]

(iii) Name the type of reaction that occurs in reaction 3.

..... [1]

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8. June/2023/Paper_9701/11/No.24

Structural isomerism and stereoisomerism should be considered when answering this question.

If a molecule contains two non-identical chiral carbon atoms, four optical isomers exist.

How many isomers are there with:

- molecular formula $C_7H_{14}O$ **and**
- a five-membered ring **and**
- a tertiary alcohol group?

A 4 **B** 5 **C** 9 **D** 13

9. June/2023/Paper_9701/11/No.26

An organic molecule W contains 3 carbon atoms. It requires 4.5 molecules of oxygen for complete combustion.

What could W be?

A propane

B propanoic acid

C propanone

D propan-1-ol

10. June/2023/Paper_9701/11/No.27

Which equation represents a reaction that proceeds through initiation, propagation and termination steps?

A $C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$

B $C_5H_{11}Br + NaOH \rightarrow C_5H_{11}OH + NaBr$

C $C_6H_{12} + H_2O \rightarrow C_6H_{13}OH$

D $C_6H_{13}CHO + HCN \rightarrow C_6H_{13}CH(OH)CN$

11. June/2023/Paper_9701/11/No.28

Structural isomerism and stereoisomerism should be considered when answering this question.

A set of isomeric hydrocarbons:

- all contain 14.3% by mass of hydrogen
- all react with bromine by addition, 0.280 g of each hydrocarbon reacting with 0.799 g of bromine.

What is the maximum number of isomeric compounds in the set?

A 1 **B** 3 **C** 4 **D** 5

12. June/2023/Paper_9701/12/No.28

Ethane reacts with an excess of chlorine in the presence of ultraviolet light to form a mixture of products.

How many of these products contain two carbon atoms and one or more chlorine atoms?

A 6 **B** 7 **C** 8 **D** 9

13. June/2023/Paper_9701/13/No.31

A mixture of ethane and an excess of chlorine is exposed to UV light.

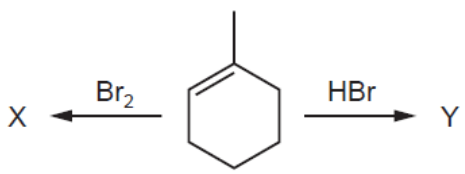
How many different products, each containing only two carbon atoms and at least one chlorine atom per molecule, can be formed?

A 8 **B** 9 **C** 10 **D** 12

14. June/2023/Paper_9701/13/No.32

When 1-methylcyclohexene reacts with Br_2 the product is X.

When 1-methylcyclohexene reacts with HBr the **major** product is Y.



Which statement is correct?

A X is a mixture of two stereoisomers; Y does **not** have stereoisomers.

B X is a mixture of two stereoisomers; Y is a mixture of four stereoisomers.

C X is a mixture of four stereoisomers; Y does **not** have stereoisomers.

D X is a mixture of four stereoisomers; Y is a mixture of four stereoisomers.

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(c) Biodiesel **T** is a fuel made from vegetable oil **R**. Fig. 5.1 shows the production of **T** from **R** in a two-step process.

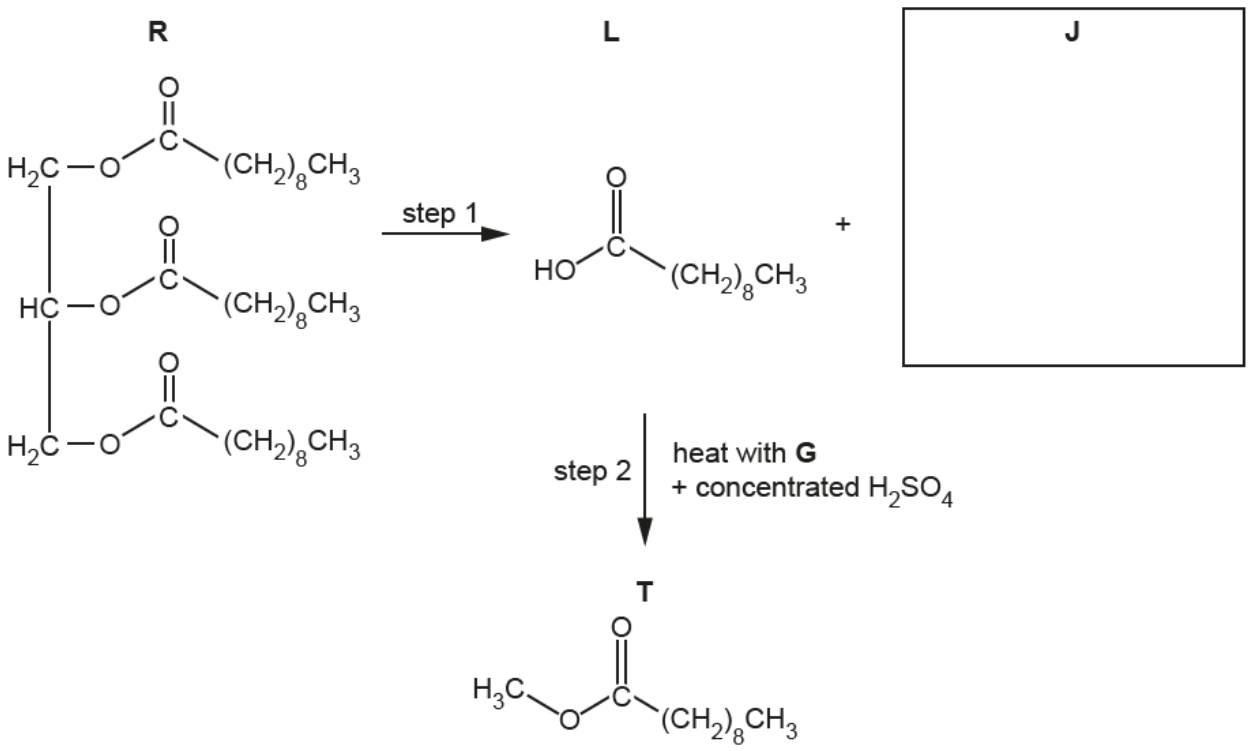


Fig. 5.1

(i) In step 1 all three ester groups in **R** react. Suggest a suitable reagent and conditions for step 1.

..... [1]

(ii) Draw the structural formula of **J** in the box in Fig. 5.1. [1]

(iii) Name the type of reaction that occurs in step 2.

..... [1]

(iv) Name organic reagent **G** used in step 2.

..... [1]

(v) **L** is called decanoic acid. Use systematic nomenclature to deduce the name of **T**.

..... [1]

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16. June/2023/Paper_9701/22/No.5(a)

(a) Describe structural isomerism.

.....

..... [1]

17. June/2023/Paper_9701/23/No.5(c, d)

Y is formed from **X** in a single-step reaction, as shown in Fig. 5.1.

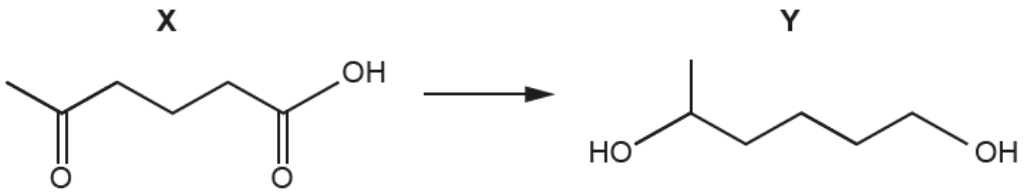


Fig. 5.1

(c) Complete Table 5.1 to show the number of sp^2 and sp^3 hybridised carbon atoms in a molecule of **X**.

Table 5.1

type of hybridisation	sp^2	sp^3
number of carbon atoms in **X**		

[2]

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(d) Complete Table 5.2 with the expected observations that occur when the reagents shown are added to separate solutions of **X** and **Y**. Do **not** refer to temperature changes in your answer.

Table 5.2

reagent	observation on addition to **X**	observation on addition to **Y**
aqueous sodium carbonate		
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)		
alkaline aqueous iodine		

[3]

18. March/2023/Paper_9701/12/No.29

Cyclohexene, C_6H_{10}, is a hydrocarbon with a six-membered ring of carbon atoms.

It has several structural isomers that are straight-chain alkenes. The number of double bonds in each of these molecules is P.

What is the shape of the cyclohexene molecule and what is the value of P?

	shape	P
A	planar	1
B	planar	2
C	non-planar	1
D	non-planar	2

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19. March/2023/Paper_9701/12/No.30

Exhaust gases from an internal combustion engine are made less harmful by passing them through a catalytic converter. A number of reactions take place in the catalytic converter. Two such reactions are described in the table.

Which row is correct?

	the type of reaction that removes carbon monoxide	the type of reaction that removes unburned hydrocarbons
A	oxidation	oxidation
B	oxidation	reduction
C	reduction	reduction
D	reduction	oxidation

20. March/2023/Paper_9701/12/No.39

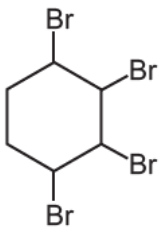
Cyclohexa-1,4-diene is treated with a solution of bromine in tetrachloromethane in the dark.



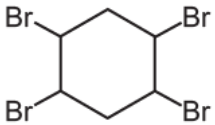
cyclohexa-1,4-diene

Which product is formed?

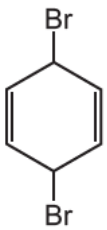
A



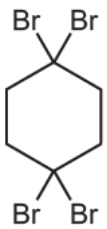
B



C



D



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21. March/2023/Paper_9701/12/No.40

2-methylbut-2-ene is reacted with hot, concentrated, acidified potassium manganate(VII) solution.

What are the products of this reaction?

A ethanal and propanone

B ethanoic acid and propanone

C ethanoic acid and propan-2-ol

D ethanol and propan-2-ol

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