AH Exercise 2.3

Synthesis

2007 AH MC29 (81%)

29. Which of the following has nucleophilic properties?

A Na

B Br^+

C CH_3^+

D NH_3

2009 AH MC24 (63%)

24. $OH^- + CO_2 \rightarrow HCO_3^-$

$C_2H_4 + Br_2 \rightarrow C_2H_4Br^+ + Br^-$

Which substances act as electrophiles in the above reactions?

A OH^- and Br_2

B OH^- and C_2H_4

C CO_2 and Br_2

D CO_2 and C_2H_4

2010 AH MC31 (53%)

31. Which of the following is most reactive as a nucleophile?

A Br_2

B CH_3I

C NH_4^+

D NH_3

2003 AH MC29 (71%) and 2010 AH MC26 (75%)

29. Which of the following does **not** occur in the reaction between methane and chlorine?

A Homolytic fission

B An addition reaction

C A chain reaction

D Free radical formation

2007 AH MC25 (60%)

25. Which of the following does **not** apply to the reaction between methane and chlorine?

It involves

A homolytic fission

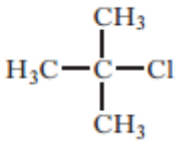
B a chain reaction

C a carbocation intermediate

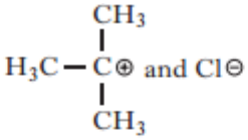
D free radicals.

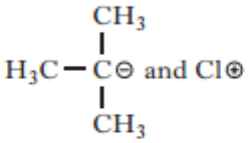
2015 revAH MC13 (83%)

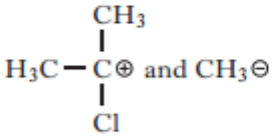
13.

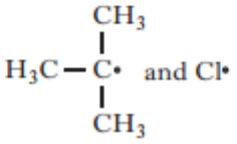


Which of the following would be the most likely products of heterolytic bond fission of the above compound?

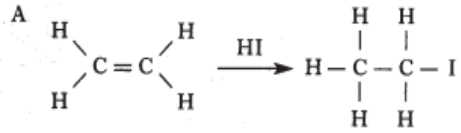
A 

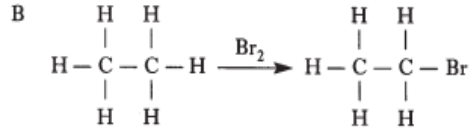
B 

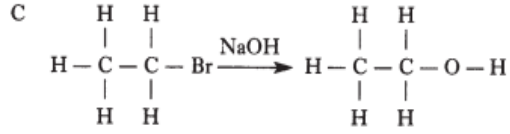
C 

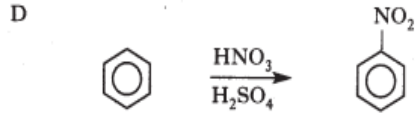
D 

2004 AH MC29 (65%)

A 

B 

C 

D 

29. Which of the above involves homolytic fission?

2005 AH MC27 (77%) and 2015 AH MC27 (88%)

27. Which of the following represents a propagation step in a chain reaction?

A $Cl\bullet + Cl\bullet \rightarrow Cl_2$

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

C $CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$

D $Cl_2 \rightarrow Cl\bullet + Cl\bullet$

2009 AH MC22 (46%)

22. Which of the following is a propagation step in the chlorination of methane?

A $Cl_2 \rightarrow Cl\bullet + Cl\bullet$

B $CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$

C $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

D $CH_4 + Cl\bullet \rightarrow CH_3Cl + H\bullet$

2011 AH MC24 (61%)

24. The reaction between chlorine and ethane to give chloroethane is an example of a chain reaction.

Which of the following is a propagation step in this reaction?

A $Cl_2 \rightarrow Cl\bullet + Cl\bullet$

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

C $C_2H_5\bullet + C_2H_5\bullet \rightarrow C_4H_{10}$

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

2013 AH MC32 (93%)

32. Which of the following represents an initiation step in a chain reaction?

A $Cl_2 \rightarrow 2Cl\bullet$

B $CH_3\bullet + CH_3\bullet \rightarrow C_2H_6$

C $CH_4 + Cl\bullet \rightarrow CH_3Cl + H\bullet$

D $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

2005 AH MC33 (66%)

33. Some alkanes may be prepared by adding an iodoalkane dropwise to sodium in a suitable solvent, eg

$$2CH_3I + 2Na \rightarrow C_2H_6 + 2NaI$$

When a mixture of iodomethane and iodoethane is used as a starting material, the product will contain

A propane only

B methane and ethane

C ethane, propane and butane

D methane, ethane, propane and butane.

2011 AH MC29 (57%)

29. Part of a possible chain reaction mechanism for chlorine reacting with methane is:

$Cl_2 \rightarrow 2Cl\bullet$

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

$CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

Which of the following will **not** be a termination step in this reaction?

A $H\bullet + Cl\bullet \rightarrow HCl$

B $Cl\bullet + Cl\bullet \rightarrow Cl_2$

C $CH_3\bullet + CH_3\bullet \rightarrow C_2H_6$

D $CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$

2006 AH MC30 (90%)

30. Which of the following represents a termination step in a chain reaction?

A $Cl\bullet + Cl\bullet \rightarrow Cl_2$

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

C $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

D $Cl_2 \rightarrow Cl\bullet + Cl\bullet$

2014 AH MC27 (54%)

27. Which of the following substances could **not** be a product in the chain reaction between ethane and chlorine?

A HCl

B C_2H_3Cl

C C_2H_5Cl

D C_4H_{10}

2008 AH MC37 (76%)

37. Which of the following could **not** exist in isomeric forms?

A C_2F_4

B C_3H_6

C C_3H_7Br

D $C_2H_4Cl_2$

2010 AH MC38 (75%)

38. Which of the following could **not** exist in isomeric forms?

A C_3H_6

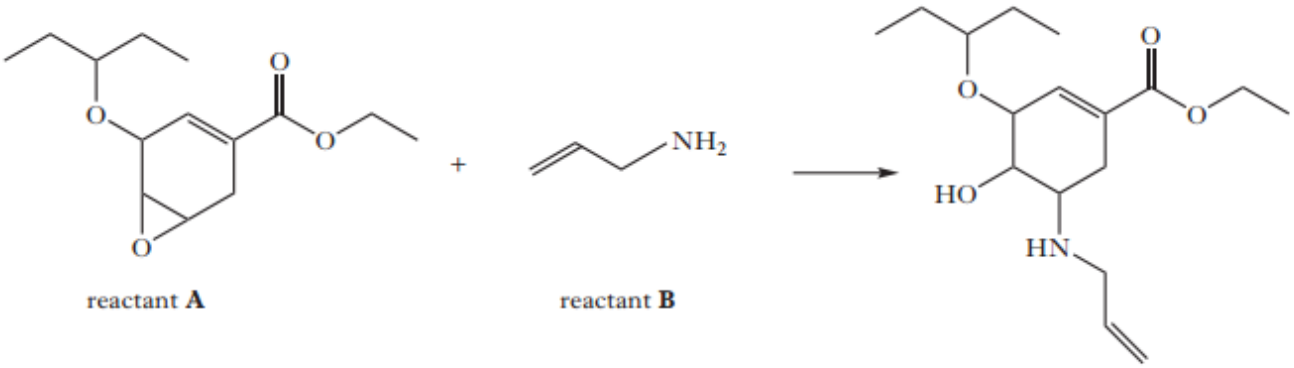
B C_3H_8

C C_3H_7Br

D $C_2H_4Cl_2$

2015 revAH L11a(i)

11. (*a*) One of the main drugs used in the treatment of bird flu is Tamiflu. One step in the synthesis is shown below.



reactant **A** reactant **B**

In this reaction, reactant **A** has an electrophilic centre and reactant **B** has a nucleophilic centre.

(i) Describe how reactant **B** is acting as a nucleophile in this reaction. **1**

2016 AH L8c

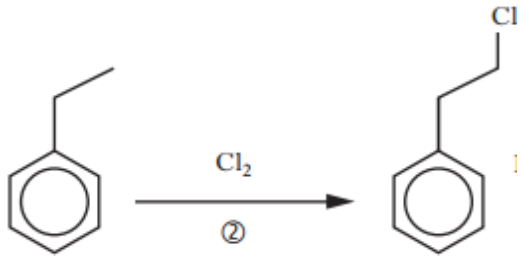
8. Aspirin can be used as a starting material for the synthesis of the drug, salbutamol, which is used in the treatment of asthma. Salbutamol acts as an agonist by stimulating receptors in the lungs.

A possible synthetic route is shown.

(c) Suggest a reaction condition required for Step ③. **1**

2013 revAH L10b

10. A student devised the following reaction sequence.



(*b*) During step ②, chlorine firstly undergoes homolytic fission.

Explain what this means. **1**

AH Exercise 2.3a

Haloalkanes

2004 AH MC28 (63%) and 2015 AH MC29 (68%) and 2015 revAH MC14 (79%)

28. Which of the following equations does **not** represent a nucleophilic substitution?

A $C_3H_7Br + KOH \xrightarrow{\text{ethanol}} C_3H_6 + KBr + H_2O$

B $C_3H_7Br + KCN \xrightarrow{\text{ethanol}} C_3H_7CN + KBr$

C $C_2H_5Cl + C_2H_5ONa \xrightarrow{\text{ethanol}} C_2H_5OC_2H_5 + NaCl$

D $C_2H_5Br + NaOH \xrightarrow{\text{water}} C_2H_5OH + NaBr$

2011 AH MC26 (82%)
2014 AH MC25 (86%) and 2014 revAH MC19 (93%)

26. Propene can be produced by heating 1-bromopropane with ethanolic potassium hydroxide.

This reaction is an example of

A reduction
B hydrolysis
C elimination
D condensation.

2001 AH MC23 (61%)

23. $C_2H_5Br + C_2H_5O^-Na^+ \rightarrow C_2H_5OC_2H_5 + Na^+Br^-$

This is an example of

A nucleophilic substitution.
B electrophilic substitution
C a condensation reaction
D an addition reaction.

2010 AH MC25 (77%)

25. $C_3H_7Cl + C_2H_5O^- \rightarrow C_3H_7OC_2H_5 + Cl^-$

The above reaction is

A an elimination reaction
B a nucleophilic addition reaction
C a nucleophilic substitution reaction
D an electrophilic substitution reaction.

2012 AH MC23 (68%)

23. 2-Bromobutane reacts with potassium hydroxide in ethanol to produce two unsaturated products.

The type of reaction involved is

A addition
B elimination
C oxidation
D substitution.

2016 AH MC20 (60%)

20. When 2-bromobutane reacts with ethanolic potassium cyanide and the compound formed is hydrolysed with dilute acid, the final product is

A butanoic acid
B pentanoic acid
C 2-methylbutanoic acid
D 2-methylpentanoic acid.

2008 AH MC30 (63%)

30. When 2-bromobutane is reacted with potassium cyanide and the compound formed is hydrolysed with dilute acid, the final product is

A butanoic acid
B pentanoic acid
C 2-methylbutanoic acid
D 2-methylpropanoic acid.

2005 AH MC28 (59%)

28. Which of the following molecules is likely to produce the most stable carbocation intermediate in a hydrolysis reaction?

A $(CH_3)_3CCl$

B CH_3CH_2Cl

C $CH_3CHICH_2CH_3$

D CH_3CH_2I

2012 AH MC25 (72%)

25. Which of the following molecules is likely to produce the most stable carbocation intermediate in a substitution reaction?

A CH_3CH_2I

B $(CH_3)_3CCl$

C CH_3CH_2Cl

D $CH_3CHICH_2CH_3$

2016 AH MC23 (61%)

23. $(CH_3)_3CBr + OH^- \rightarrow (CH_3)_3COH + Br^-$

The above reaction proceeds via an S_N1 mechanism.

What effect will doubling the concentration of hydroxide ions have on the reaction rate?

A It will have no effect.

B The reaction rate will halve.

C The reaction rate will double.

D The reaction rate will increase by a factor of four.

2003 AH MC35 (83%) and 2007 AH MC33 (80%)

35. Which of the following is the formula for a tertiary halogenoalkane?

A $(CH_3)_3CBr$

B $CHBr_3$

C $CH(CH_2Br)_3$

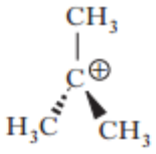
D $(CH_3)_3CCH_2Br$

2009 AH MC23 (61%)

23. The hydrolysis of the halogenoalkane $(CH_3)_3CBr$ was found to take place by an S_N1 mechanism.

The rate-determining step involved the formation of

A



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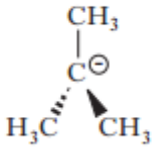

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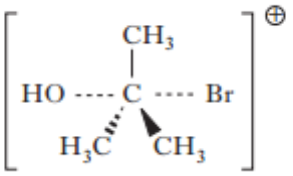

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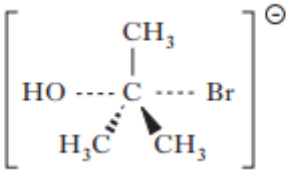


2016 AH MC16 (42%)

16. Which of the following will react together to produce 2-ethoxypropane?

A CH_3CH_2OH and CH_3CH_2COONa

B CH_3CH_2ONa and $CH_3CH_2CH_2Br$

C $CH_3CH(OH)CH_3$ and CH_3COONa

D CH_3CH_2ONa and $CH_3CHBrCH_3$

2002 AH MC27 (66%)

2014 AH MC29 (64%) and 2014 revAH MC21 (71%)

27. Which of the following will react to form $CH_3CH_2OCH_2CH_2CH_3$?

A CH_3CH_2OH and CH_3CH_2COONa

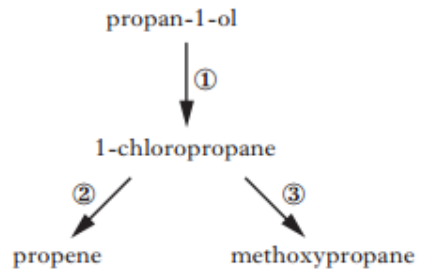
B CH_3CH_2ONa and $CH_3CH_2CH_2I$

C $CH_3CH_2CH_2OH$ and CH_3COONa

D CH_3CH_2ONa and CH_3CHICH_3

2013 revAH MC23 (84%)

23.

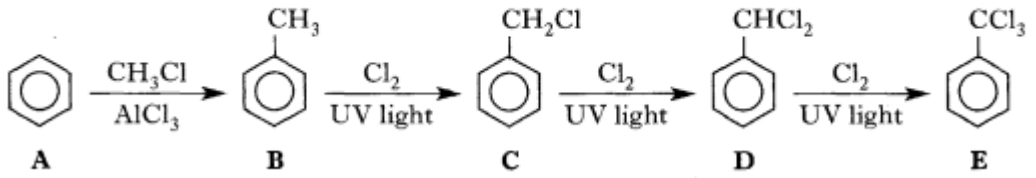


Which line in the table is correct for the types of reaction taking place at ①, ② and ③?

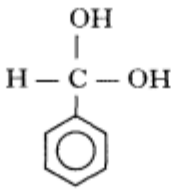
	Reaction ①	Reaction ②	Reaction ③
A	substitution	elimination	substitution
B	substitution	reduction	substitution
C	addition	reduction	condensation
D	addition	elimination	substitution

2002 AH L6d

6. Consider the following reaction sequence.



(*d*) **D** reacts with aqueous sodium hydroxide to form



which is unstable and immediately loses water to form a stable aldehyde.

Compound **E** reacts in a similar way with aqueous sodium hydroxide forming an intermediate which also loses water to give a stable product.

Draw the structure of this stable product. **1**

2002 AH L10a+b

10. Butanoic acid can be synthesised from 1-bromopropane by a two stage process.

$$CH_3CH_2CH_2Br \xrightarrow[KCN(aq)]{\text{stage 1}} \mathbf{Y} \xrightarrow{\text{stage 2}} CH_3CH_2CH_2COOH$$

(*a*) Draw the structural formula of **Y**. **1**

(*b*) Name the type of reaction taking place in stage **2**. **1**

2001 AH L8a+d

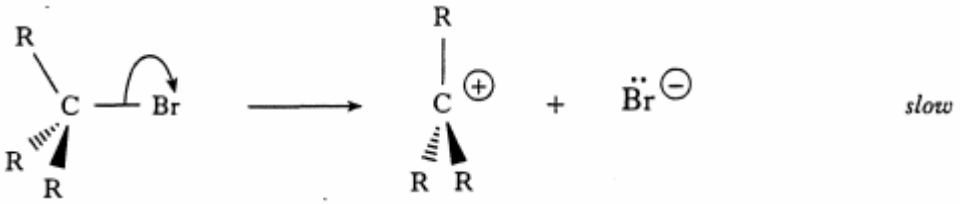
8. Bromoalkanes undergo nucleophilic substitution when heated with aqueous sodium hydroxide solution.

$$R_3CBr + OH^- \rightarrow R_3COH + Br^-$$

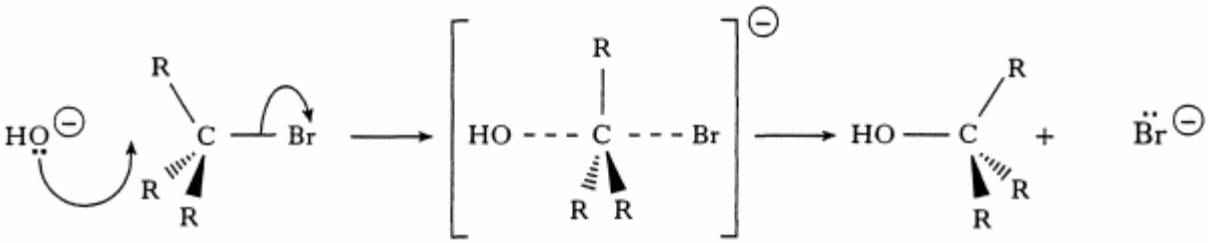
(where R = H and/or an alkyl group)

Two possible mechanisms for the reaction are outlined below.

Mechanism 1 (two-step process):

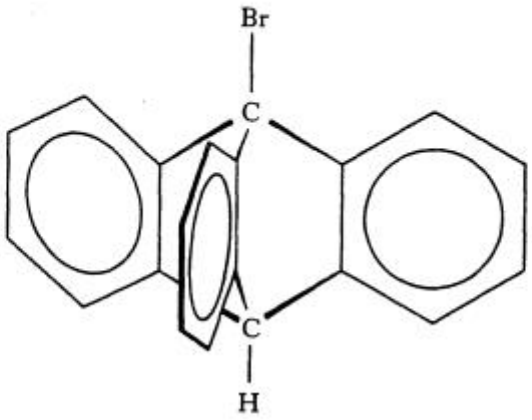


Mechanism 2 (single-step process):



(*a*) Explain what is meant by the term, *nucleophilic substitution*.

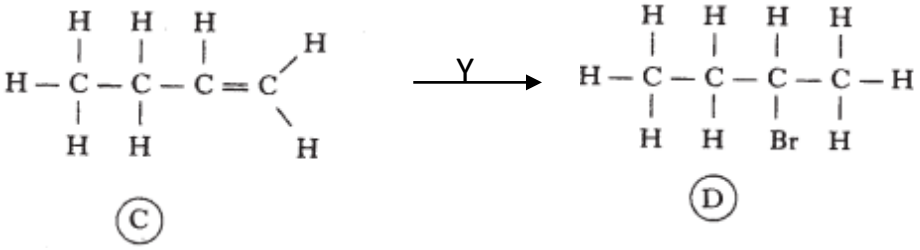
(*d*) Suggest why the compound shown below is unlikely to undergo reaction with sodium hydroxide by **mechanism 2**.



1

2003 AH L5a(ii)

5. A student designed the following reaction sequence.



C D

(*a*) Suggest a suitable reagent to carry out

(ii) step Y.

2003 AH L6

MARK

6. 1-Bromobutane and 2-bromo-2-methylpropane are isomers which can be converted to their corresponding alcohols using hydroxide ions.

(*a*) The conversion of 2-bromo-2-methylpropane to 2-methylpropan-2-ol involves an S_N1 mechanism.

(i) Explain the meaning of the abbreviation S_N1. **2**

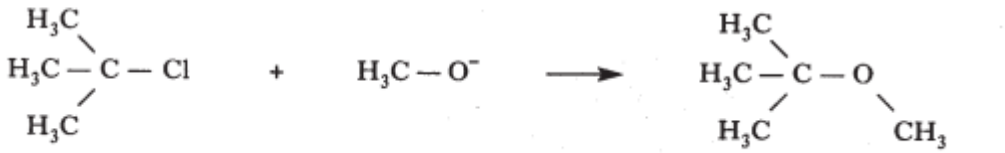
(ii) Outline the two steps in this mechanism using structural formulae. **2**

(*b*) Explain why the conversion of 1-bromobutane to butan-1-ol is unlikely to proceed by an S_N1 mechanism. **1**

(c) 2-Bromo-2-methylpropane reacts with ethoxide ions to form an ether. Draw a structural formula for this ether. **1**

2004 AH L10c

10. 2-Methoxy-2-methylpropane is a compound added to unleaded petrol as a "knock inhibitor". It can be synthesised by the reaction of methoxide ions with 2-chloro-2-methylpropane.



2-chloro-2-methylpropane methoxide ion 2-methoxy-2-methylpropane

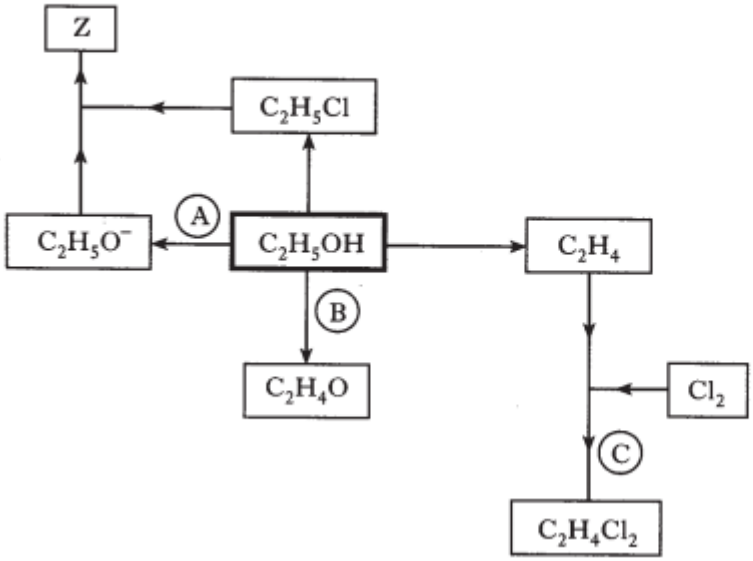
(*c*) The preparation of the 2-methoxy-2-methylpropane proceeds by a S_N1 mechanism.

(i) Clearly showing the electron shifts, outline the step(s) involved. **2**

(ii) Suggest why this reaction is more likely to proceed by a S_N1 mechanism rather than a S_N2. **1**

2005 AH L9b

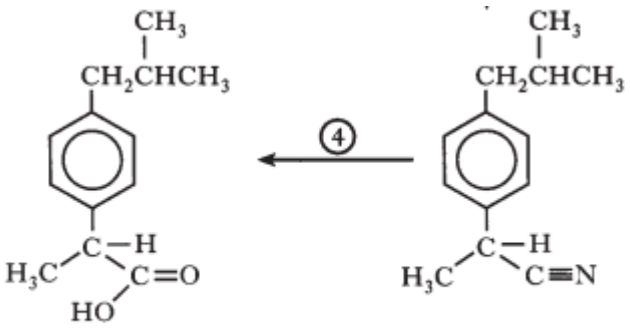
9. A student designed the following reaction sequence based on ethanol, C_2H_5OH.



(*b*) Draw a structural formula for **Z**. **1**

2005 AH L10b

10. Ibuprofen is an anti-inflammatory agent which can be synthesised from benzene as shown below.

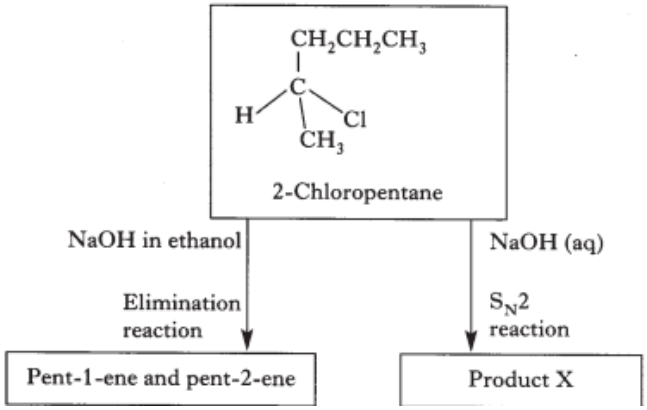


ibuprofen

(*b*) Suggest a suitable reagent to carry out step ④. **1**

2005 AH L11a

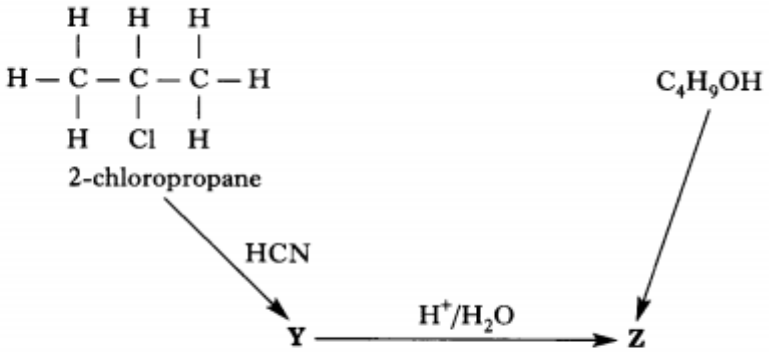
11. In the reaction sequence shown below, 2-chloropentane reacts with sodium hydroxide in different ways depending on the solvent used.



(*a*) Outline the mechanism for the S_N2 reaction using structural formulae. **2**

2006 AH L12a+b+d

12. The diagram illustrates two methods of preparing compound **Z**.



(*a*) Draw a structural formula for compound **Y**. **1**

(*b*) Compound **Z** has the molecular formula $C_4H_8O_2$.
Name **and** draw a structural formula for compound **Z**. **2**

(*d*) The conversion of 2-chloropropane into compound **Y** proceeds by an S_N2 mechanism.

(i) Explain what is meant by the abbreviation S_N2. **2**

(ii) Draw a structural formula for the transition state in this reaction. **1**

2008 AH L10a

10. A mixture of butan-1-ol and butan-2-ol can be synthesised from 1-bromobutane in a two stage process.

$$CH_3CH_2CH_2CH_2Br \xrightarrow[\textbf{Stage 1}]{KOH/C_2H_5OH} CH_3CH_2CH{=}CH_2 \xrightarrow[\textbf{Stage 2}]{H_2O/H^+} \begin{matrix}\text{butan-1-ol}\\+\\\text{butan-2-ol}\end{matrix}$$

(*a*) What type of reaction is taking place in **Stage 1**? **1**

2008 AH L11b

11. A student devised the following reaction sequence starting from propan-1-ol, C_3H_7OH.

$$C_3H_7OH \xrightarrow{(1)} C_3H_7O^- \xrightarrow[(2)]{C_2H_5Cl} \mathbf{Y}$$

(*b*) Name **Y**. **1**

2009 AH L9b

9. Compound **W** reacts in two steps to form compound **Y**.

$$\underset{\mathbf{W}}{C_4H_9Br} \xrightarrow{(1)} \underset{\mathbf{X}}{C_4H_{10}O} \xrightarrow{(2)} \underset{\mathbf{Y}}{C_4H_8O}$$

(*b*) What type of reaction is occurring in step (1)? **1**

2010 AH L11c

11. Consider the following reaction scheme.

$$(B)\quad CH_3CHBrCH_2CH_3 \longrightarrow (C)\quad \text{butan-2-ol}$$

(*c*) Name a reagent used to convert (B) to (C). **1**

2011 AH L13

13. When sodium hydroxide solution was added to 2-bromomethylpropane an S_N1 reaction took place producing methylpropan-2-ol and hydrobromic acid.

(*a*) (i) What is meant by an S_N1 reaction? **2**

(ii) Draw the structure of the carbocation intermediate formed in this reaction. **1**

(*b*) Chloromethane reacts with sodium ethoxide in an S_N2 reaction.

(i) How is sodium ethoxide prepared in the laboratory? **1**

(ii) Name the organic product of this S_N2 reaction. **1**

2012 AH L15a+b

15. Chloroalkane **A** has molecular formula C_4H_9Cl. When **A** is heated with NaOH(aq), it undergoes an S_N2 reaction to form alcohol **B**.

Alcohol **B** can be oxidised by acidified potassium dichromate solution and it can also be dehydrated to produce a mixture of two alkenes which are structural isomers.

(*a*) Draw a structural formula for compound **A**. **1**

(*b*) Draw the structure of the transition state involved in this S_N2 reaction. **1**

2013 AH L8d and <u>2013</u> revAH L8d+e

8. A kinetics study was carried out on the reaction between a halogenoalkane, C_4H_9Br, and aqueous sodium hydroxide.

$$C_4H_9Br + NaOH \rightarrow C_4H_9OH + NaBr$$

The following results were obtained.

$[C_4H_9Br]$/mol l^{-1}	[NaOH]/mol l^{-1}	Initial Rate/mol $l^{-1}s^{-1}$
$8{\cdot}0 \times 10^{-4}$	0·10	0·15
$1{\cdot}6 \times 10^{-3}$	0·10	0·30
$1{\cdot}6 \times 10^{-3}$	0·20	0·30
$3{\cdot}2 \times 10^{-3}$	0·40	0·60

(*d*) There are four structural isomers of C_4H_9Br.

(i) From the above results, which isomer is most likely to have been used? **1**

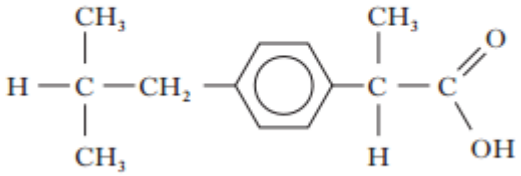
(ii) Explain your answer to (*d*)(i). **1**

(*e*) Outline the mechanism for this reaction using curly arrow notation. **3**

2014 AH L8(iii) and 2014 revAH L9b(iii)

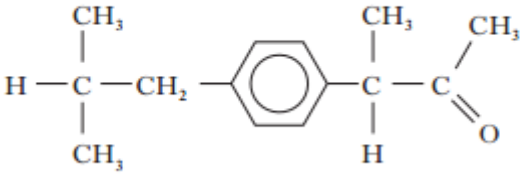
8. Ibuprofen is one of the most commonly used non-steroidal anti-inflammatory drugs (NSAIDs).

The structure of ibuprofen is shown.

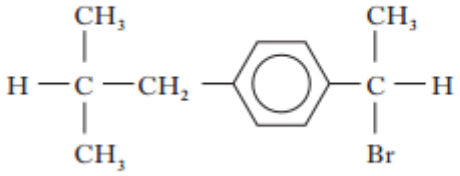


ibuprofen

(*b*) Compounds **A** and **B**, shown below, can be used to manufacture ibuprofen.



A



B

(iii) Suggest how compound **B** could be converted into ibuprofen. **2**

2014 AH L10c and 2014 AH L11c

10. The results of experiments on the alkaline hydrolysis of 2-iodobutane, $CH_3CHIC_2H_5$, are shown in the table below.

The equation for the hydrolysis is

$$CH_3CHIC_2H_5(\ell) + OH^-(aq) \rightarrow CH_3CH(OH)C_2H_5(\ell) + I^-(aq)$$

Experiment	$[CH_3CHIC_2H_5]$/mol l^{-1}	$[OH^-]$/mol l^{-1}	Initial Rate/mol $l^{-1}s^{-1}$
1	0·10	0·10	$1{\cdot}4 \times 10^{-4}$
2	0·20	0·20	$2{\cdot}9 \times 10^{-4}$
3	0·30	0·10	$4{\cdot}1 \times 10^{-4}$

(*c*) Using structural formulae and your answers to part (*a*), outline the mechanism for the above reaction. **2**

2015 AH L10a+b+c+d and 2015 revAH L10a+b+c+d

10. There are four isomers with the molecular formula C_4H_9Cl. Structural formulae for three of these isomers are

$CH_3CHClCH_2CH_3$ $(CH_3)_2CHCH_2Cl$ $(CH_3)_3CCl$

A **B** **C**

(*a*) What is the systematic name of isomer **C**? **1**

(*b*) When refluxed with a solution of potassium hydroxide in ethanol, compound **A** undergoes an elimination reaction. Two structural isomers are produced.

Draw a structural formula for each of these two isomers. **2**

(*c*) Isomer **B** reacts with aqueous sodium hydroxide in an S_N2 reaction.

Isomer **B** Compound **X**

(i) Name compound **X**. **1**

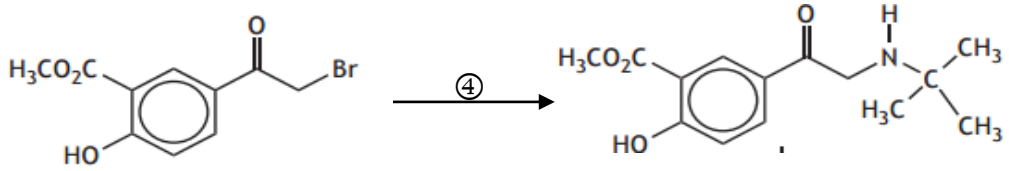
(ii) Draw a structure for the transition state in this reaction. **1**

(*d*) Draw a structural formula for the fourth isomer of C_4H_9Cl. **1**

2016 AH L8d

8. Aspirin can be used as a starting material for the synthesis of the drug, salbutamol, which is used in the treatment of asthma. Salbutamol acts as an agonist by stimulating receptors in the lungs.

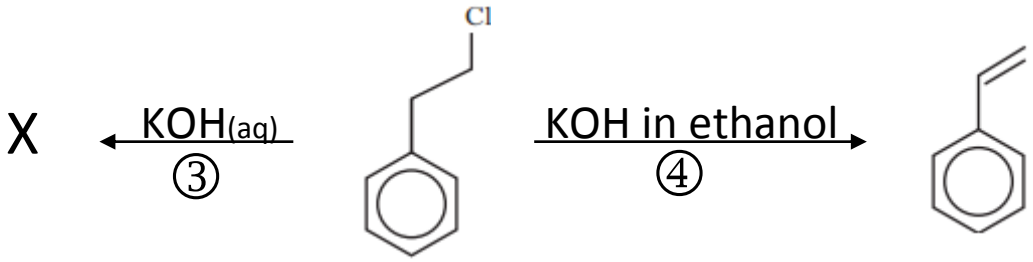
A possible synthetic route is shown.



(d) Identify the type of reaction taking place in Step ④. **1**

2013 revAH L10c+d

10. A student devised the following reaction sequence.



(*c*) Draw a structural formula for product **X**. **1**

(*d*) What type of reaction is taking place in step ④? **1**

AH Exercise 2.3b

Alcohols

2004 AH MC32 (94%)

32. Which formula represents 2-methylpentan-3-ol?

A $CH_3CH(CH_3)CH(OH)CH_2CH_3$

B $CH_3CH(OH)CH(CH_3)CH_2CH_3$

C $CH_3CH(CH_3)CH(OH)CH_3$

D $CH_3CH_2C(CH_3)_2CH_2CH_2OH$

2008 AH MC25 (79%)

25. In the homologous series of alkanols, increase in chain length from CH_3OH to $C_{10}H_{21}OH$ is accompanied by

A increased volatility and increased solubility in water

B increased volatility and decreased solubility in water

C decreased volatility and decreased solubility in water

D decreased volatility and increased solubility in water.

2010 AH MC32 (67%)

32. Hydrogen bonding occurs in

A CH_3I

B CH_3OH

C CH_3OCH_3

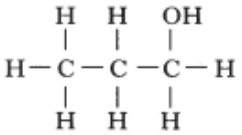
D CH_3CH_2CHO.

2005 AH MC29 (68%)

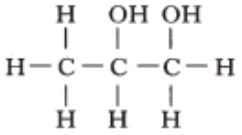
2011 AH MC27 (67%) and 2015 AH MC31 (77%)

29. The structures of three alcohols, **P**, **Q** and **R** are shown.

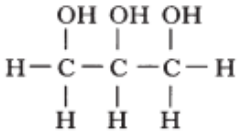
P



Q



R



Which line in the table describes correctly the trends in boiling points and viscosities on moving from **P** to **Q** to **R**?

	Boiling point	Viscosity
A	increases	increases
B	increases	decreases
C	decreases	increases
D	decreases	decreases

2012 AH MC33 (92%)

33. Which of the following could be the molecular formula for a ketone?

A C_3H_8O

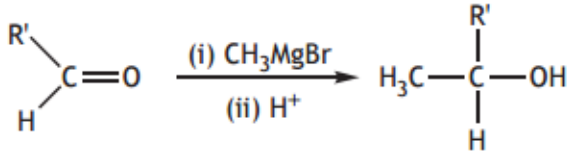
B C_3H_6O

C C_2H_4O

D CH_2O

2016 AH MC17 (83%)

17. Aldehydes can be converted into alcohols by the reaction shown



Which of the following aldehydes would produce a primary alcohol?

A Methanal

B Ethanal

C Propanal

D Butanal

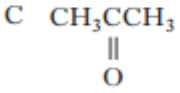
2007 AH MC35 (64%)

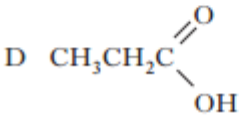
35. A substance, X, is **readily** oxidised by acidified potassium dichromate solution to give a product which does **not** react with sodium carbonate, **nor** with Tollens' reagent.

Which of the following could represent the structure of X?

A $CH_3CH_2CH_2OH$

B $CH_3CH(OH)CH_3$

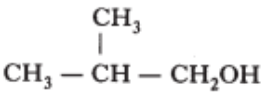
C 

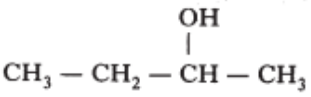
D 

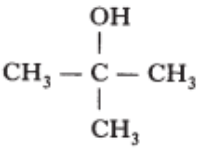
2004 AH MC33 (65%)

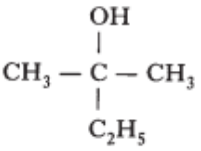
33. An alcohol, **X**, does **not** react with acidified dichromate solution, but gives an alkene when dehydrated with hot concentrated sulphuric acid. This alkene reacts with bromine water to form 1,2-dibromo-2-methylpropane.

Which of the following is **X**?

A 

B 

C 

D 

2009 AH MC28 (52%) and 2015 revAH MC15 (48%)

28. Which of the following reacts with ethanol to form the ethoxide ion?

A Na(s)

B $Na_2O(s)$

C NaCl(aq)

D NaOH(aq)

2003 AH MC34 (55%)

34. A compound, X, reduces hot copper(II) oxide and the organic product dissolves in water forming a neutral solution.

X could be

A an aldehyde

B a ketone

C a secondary alcohol

D a tertiary alcohol.

2009 AH MC31 (55%)

31. Which of the following compounds could **not** be oxidised by acidified potassium dichromate solution?

A CH_3CH_2CHO

B CH_3CH_2COOH

C $CH_3CH_2CH_2OH$

D $CH_3CH(OH)CH_3$

2007 AH MC36 (53%) and 2008 AH MC31 (48%)

36. Which of the following compounds would liberate one mole of hydrogen gas if one mole of it reacts with two moles of sodium?

A C_2H_5OH

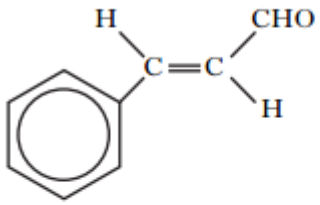
B $HOCH_2CH_2OH$

C CH_3COOH

D CH_3CHO

2010 AH MC33 (89%)

33. Cinnamaldehyde, which can be extracted from cinnamon, has the structure:



Cinnamaldehyde will **not** react with

A sodium metal

B bromine solution

C lithium aluminium hydride

D acidified potassium dichromate.

2001 AH grid32d

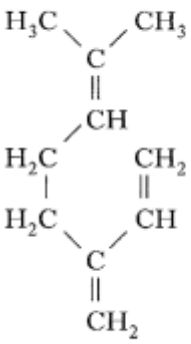
32. The boxes in the grid below contain formulae of some compounds.

A CO_2	B PCl_5	C $AlCl_3$
D CuO	E PCl_3	F $LiAlH_4$

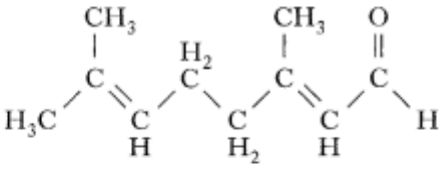
(*d*) Identify the compound(s) which can be used to reduce ethanal to ethanol.

2002 AH L12d

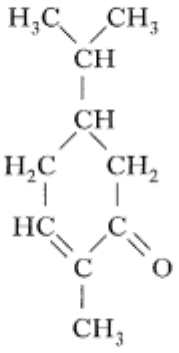
12. Myrcene, citral and carvone belong to a large group of compounds known as terpenes.



myrcene

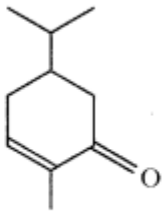


citral



carvone

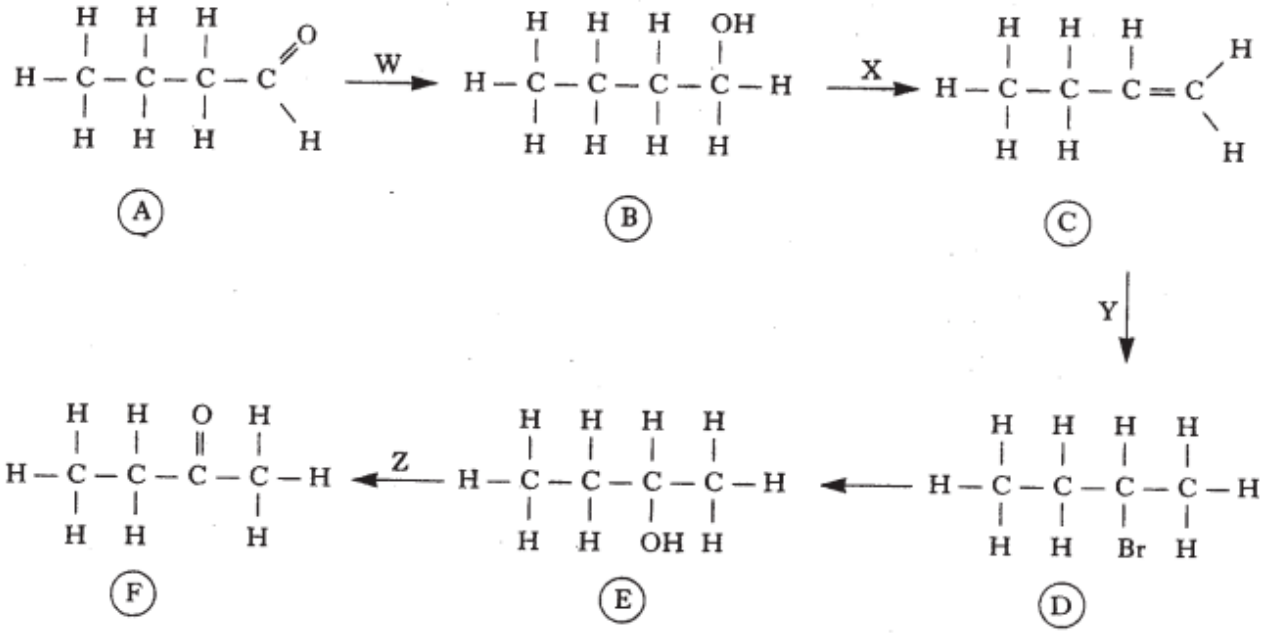
(*d*) The skeletal structural formula of carvone is



Draw the skeletal structural formula of citral. **1**

2003 AH L5a(i) + 5b(ii)

5. A student designed the following reaction sequence.



(*a*) Suggest a suitable reagent to carry out

(i) step W

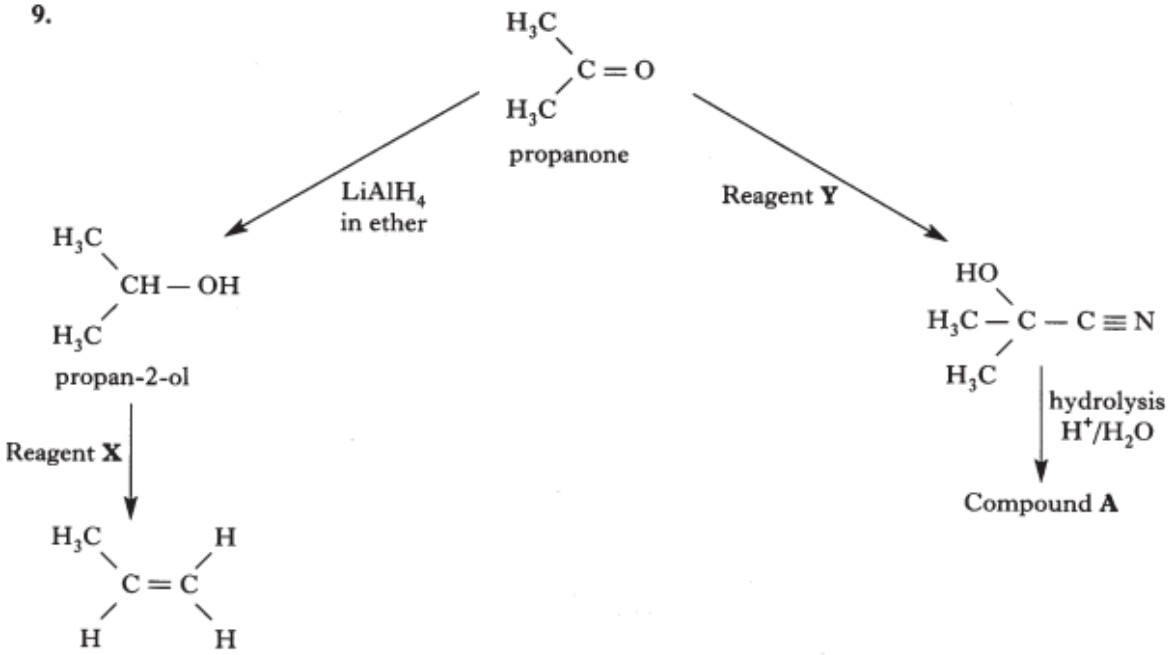
(*b*) What type of reaction occurs at

(ii) step Z?

2

2004 AH L9a(i) + 9c

9.



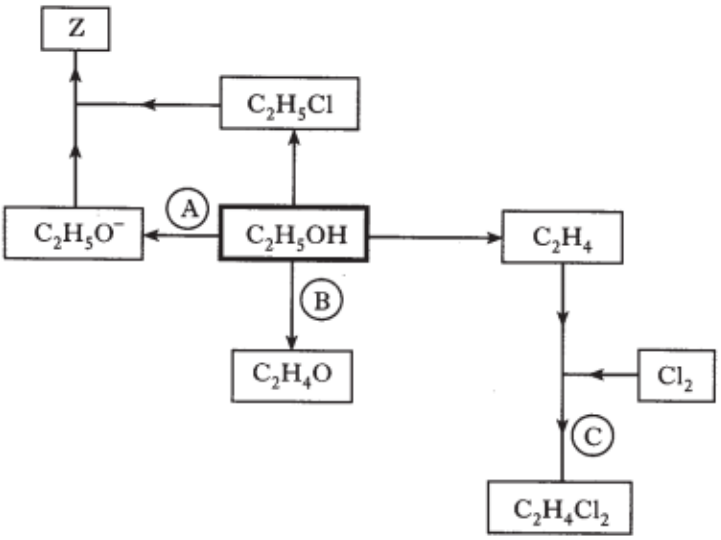
(*a*) Identify:

(i) reagent **X**; **1**

(c) Name the type of reaction involved in the conversion of propanone to propan-2-ol. **1**

2005 AH L9a

9. A student designed the following reaction sequence based on ethanol, C_2H_5OH.



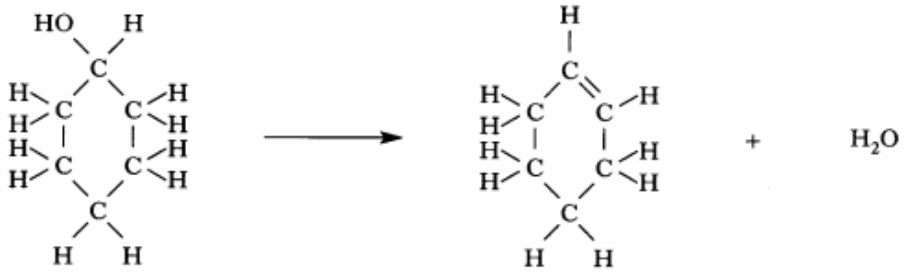
(*a*) Suggest a suitable reagent to carry out

(i) Step (A) **1**

(ii) Step (B). **1**

2006 AH L8a+b

8. In a **PPA**, cyclohexene was prepared from cyclohexanol by dehydration.



(*a*) Which reagent was used to convert cyclohexanol to cyclohexene? **1**

(*b*) Distillation was used to separate the cyclohexene product from the reaction mixture because cyclohexanol has a higher boiling point than cyclohexene.

Explain why cyclohexanol has the much higher boiling point. **1**

2006 AH L9a

9. Mixtures of the isomers of the alcohol, $C_5H_{11}OH$, are used as solvents for resins and oily materials.

The shortened structural formulae for four of these isomers are shown in the table.

Isomer	Shortened structural formula
A	$(CH_3)(C_2H_5)CHCH_2OH$
B	$(CH_3)_3CCH_2OH$
C	$(CH_3)_2(C_2H_5)COH$
D	$(C_2H_5)_2CHOH$

(*a*) Which isomer is the tertiary alcohol? **1**

2006 AH L10

10. Fusel alcohols are components of fusel oil which is obtained during the process of brewing beer. They contribute to the flavour of the beer and are also the major cause of hangovers. The most important fusel alcohols are

3-methylbutan-1-ol
2-methylbutan-1-ol
propan-1-ol.

(*a*) Give a reason why propan-1-ol is the most soluble of these alcohols in water. **1**

(*b*) Other flavours found in beer are caused by esters.

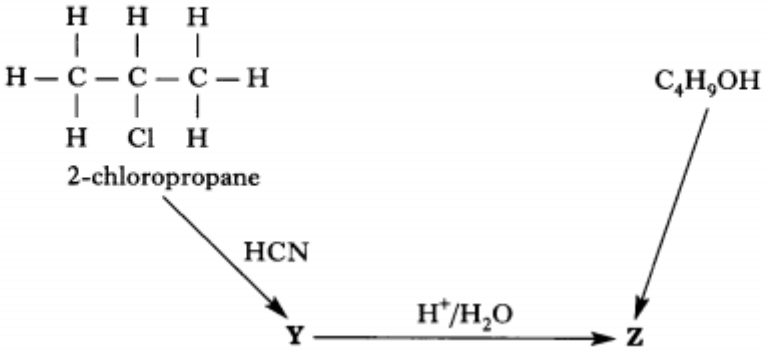
Esters can be formed by reacting alcohols with carboxylic acids.

(i) What can be used in place of carboxylic acids to form esters? **1**

(ii) What advantage is there in using this type of reagent? **1**

2006 AH L12c

12. The diagram illustrates two methods of preparing compound **Z**.

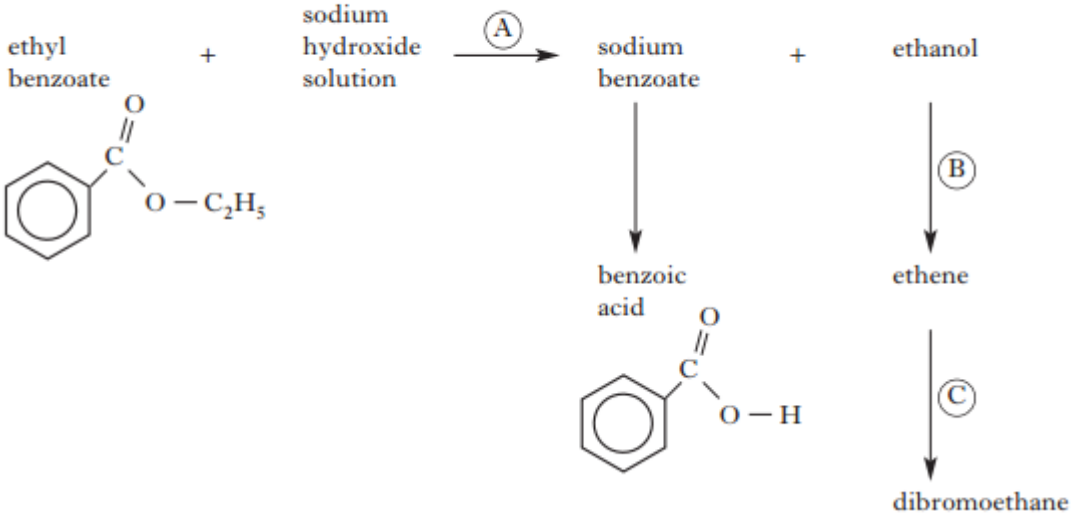


(*c*) (i) Name the alcohol, C_4H_9OH, used to prepare compound **Z**. **1**

(ii) Which reagent could be used to convert C_4H_9OH to compound **Z**? **1**

2007 AH L12b(i)

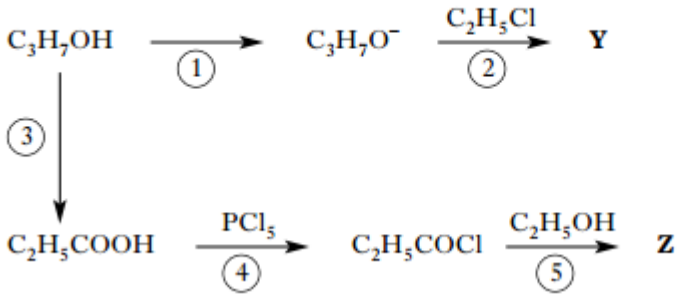
12. A student designed the following reaction scheme starting from ethyl benzoate.



(*b*) (i) Name the type of reaction occurring in step (B). **1**

2008 AH L11a+c

11. A student devised the following reaction sequence starting from propan-1-ol, C_3H_7OH.



(*a*) Name a suitable reagent to carry out

(i) Step (1)

(ii) Step (3). **2**

(*c*) Draw a structural formula for **Z**. **1**

2008 AH L12c(i)

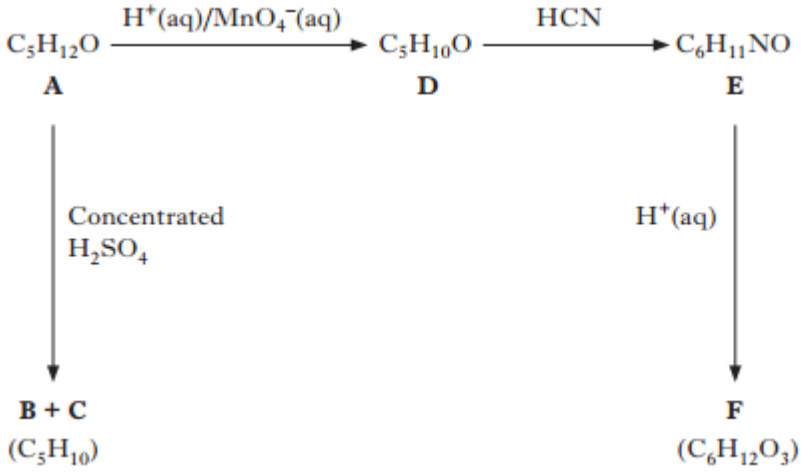
12. In a PPA, propanone reacts with 2,4-dinitrophenylhydrazine to make the 2,4-dinitrophenylhydrazone derivative

(*c*) Propanone has an isomer. The shortened structural formula of this isomer is CH_3CH_2CHO.

(i) Which chemical reagent could be used to distinguish between propanone and this isomer and what would be the result? **1**

2013 AH L13b

13. The diagram below shows a reaction sequence starting from compound **A** which is pentan-2-ol ($C_5H_{12}O$).



Compound **B** can exist as two geometric isomers.

Compound **C** is pent-1-ene.

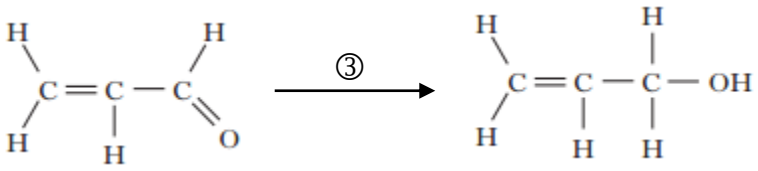
Compound **D** is the oxidation product of compound **A**.

(*b*) Name compound **D**. **1**

2014 AH L7b(iii) and 2014 revAH L8b(iii)

7. Methanal is the simplest aldehyde and propenal is the simplest unsaturated aldehyde.

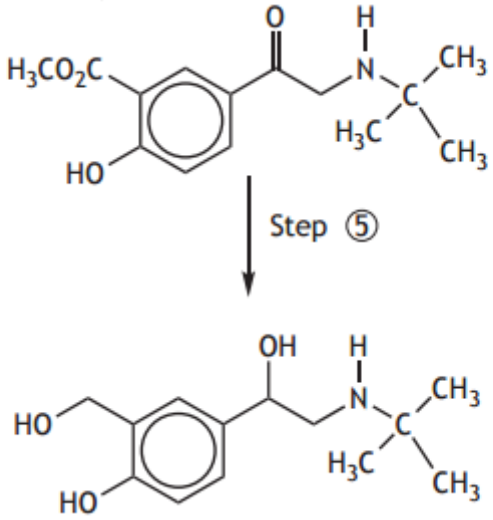
(*b*) Some possible reactions of propenal are shown below.



(iii) Which reagent could be used to carry out reaction③? **1**

2016 AH L8e

8. Aspirin can be used as a starting material for the synthesis of the drug, salbutamol, which is used in the treatment of asthma. Salbutamol acts as an agonist by stimulating receptors in the lungs.



(e) Step ⑤ involves several reactions.

Suggest a suitable reagent that could be used to convert the ketone carbonyl group to the hydroxyl group. **1**

AH Exercise 2.3c

Ethers

2001 AH MC6 (66%) and 2014 AH MC28 (71%) and 2014 revAH MC20 (79%)

6. The formula $C_4H_{10}O$ could represent an alcohol (C_4H_9OH) or an ether ($C_2H_5OC_2H_5$).

Which of the following statements would **not** be true about **both** compounds?

A They can be made by nucleophilic substitution from a halogenoalkane.

B They have hydrogen bonds between their molecules.

C They are used as solvents.

D They are flammable.

2008 AH MC26 (70%)

26. Which of the following is **not** caused by hydrogen bonding?

A The low density of ice compared to water

B The solubility of methoxymethane in water

C The higher boiling point of methanol compared to ethane

D The higher melting point of hydrogen compared to helium

2013 AH MC33 (77%) and 2013 revAH MC25 (81%)

33. Which of the following compounds would be expected to have the highest boiling point?

A Pentanal

B Pentan-2-ol

C Pentan-2-one

D Ethoxypropane

2002 AH MC26 (67%)

26. Which of the following compounds would be expected to have the highest boiling point?

A Methoxyethane

B Propanal

C Propan-2-ol

D Propanone

2003 AH MC31 (70%)

31. Which statement about ethanol and its isomer, methoxymethane, is true?

A They have similar volatility.

B They have similar reactivity.

C They produce similar infra-red spectra.

D They produce similar products when burned in excess oxygen.

2008 AH MC29 (71%)

29. Which statement about ethanol and its isomeric ether is true?

They

A have similar volatilities

B have similar infra-red spectra

C form the same products when burned in excess oxygen

D form the same products when reacted with acidified dichromate.

2006 AH MC31 (74%)

31. Which one of the following statements about ethoxyethane is **not** correct?

A It burns readily in air.

B It is isomeric with butan-1-ol.

C It has a higher boiling point than butan-1-ol.

D It may be prepared from sodium ethoxide and bromoethane.

2009 AH MC29 (78%)

29. Which of the following is **not** a correct statement about ethoxyethane?

A It burns readily in air.

B It is isomeric with butan-2-ol.

C It has a higher boiling point than butan-2-ol.

D It is a very good solvent for many organic compounds.

2008 AH MC27 (73%)

27. A compound C_3H_8O does **not** react with sodium and is **not** reduced by lithium aluminium hydride. It is likely to be an

A acid

B ether

C alcohol

D aldehyde.

2013 AH MC35 (61%) and 2013 revAH MC26 (62%)

35. The Williamson synthesis for the preparation of unsymmetrical ethers (ROR′) starting with an alcohol and a halogenoalkane is summarised in the general equations:

Step 1: $ROH + Na \rightarrow RO^-Na^+ + \frac{1}{2}H_2$

Step 2: $RO^-Na^+ + R'X \rightarrow ROR' + Na^+X^-$

Using propan-2-ol and 2-chlorobutane, the unsymmetrical ether formed would be

A $CH_3CH_2CH_2OCH(CH_3)CH_2CH_3$

B $CH_3CH_2CH_2OCH_2CH_2CH_2CH_3$

C $CH_3CH(CH_3)OCH_2CH_2CH_2CH_3$

D $CH_3CH(CH_3)OCH(CH_3)CH_2CH_3$

2013 AH MC34 (79%)

34. Which line in the table shows a general formula which does **not** match the homologous series?

	General formula	Homologous series
A	$C_nH_{2n}O$	alkanals
B	$C_nH_{2n}O_2$	alkanoic acids
C	$C_nH_{2n+2}O$	alkanols
D	$C_nH_{2n}O$	ethers

2015 AH MC32 (40%)

32. Which of the following would be required to convert a halogenoalkane into an ether?

A Aqueous sodium hydroxide followed by oxidation

B Potassium cyanide followed by hydrolysis

C Sodium hydroxide in ethanol

D Sodium in ethanol

2016 AH MC14 (85%)

14. Which of the following does **not** exhibit hydrogen bonding between its molecules?

A Ethanol

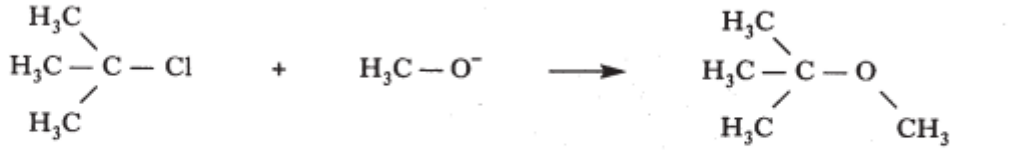
B Ethylamine

C Ethanoic acid

D Ethoxyethane

2004 AH L10a+b

10. 2-Methoxy-2-methylpropane is a compound added to unleaded petrol as a "knock inhibitor". It can be synthesised by the reaction of methoxide ions with 2-chloro-2-methylpropane.



2-chloro-2-methylpropane + methoxide ion → 2-methoxy-2-methylpropane

(*a*) To which class of organic compounds does 2-methoxy-2-methylpropane belong? **1**

(*b*) How can the methoxide ion be prepared from methanol? **1**

2001 AH L12c

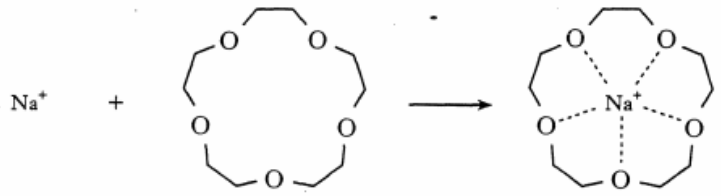
12. An alkali metal halide can adopt one or other of two different structures. They are:

- the "sodium chloride" type structure and
- the "caesium chloride" type structure.

(*c*) Alkali metal halides are generally insoluble in organic solvents but some dissolve in organic liquids called crown ethers.

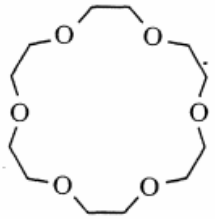
A crown ether is a ring compound and it will bind certain metal ions depending on the size of its cavity.

Sodium chloride, for example, will dissolve in [15]-crown-5 ether because the diameter of the Na^+ ion (190 pm) matches closely the cavity diameter of the crown ether (170–220 pm).



[15]-crown-5 ether

Potassium chloride does **not** dissolve in [15]-crown-5 ether but does dissolve in:



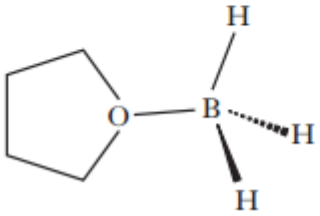
(i) Explain why potassium chloride will not dissolve in [15]-crown-5 ether. **1**

(ii) Suggest a name for the crown ether in which potassium chloride dissolves. **1**

2012 AH L4c

4. BH_3 in the gas phase is very reactive. It readily combines with the compound tetrahydrofuran, C_4H_8O, to make a more stable compound.

$$BH_3 + C_4H_8O \rightarrow C_4H_8OBH_3$$



(*c*) To which class of organic compound does tetrahydrofuran belong? **1**

2014 revAH L5

5. An organic acid can be extracted from a reaction mixture using ethoxyethane. 100 cm^3 of ethoxyethane were added to 500 cm^3 of an aqueous organic acid and the mixture shaken. After being allowed to settle, two immiscible layers formed.

(*a*) Draw a structural formula for ethoxyethane. **1**

AH Exercise 2.3d

Alkenes

2005 AH MC32 (79%)

32. Alkenes may **not** be prepared by

A thermal cracking of alkanes

B partial hydrogenation of alkynes

C dehydration of primary alcohols

D direct synthesis from carbon and hydrogen.

2007 AH MC34 (80%)

34. A compound, X, has the formula C_6H_{12}. X **must** be

A a hydrocarbon

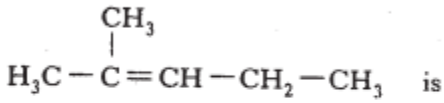
B an alkene

C a cycloalkane

D hexene.

2003 AH MC39 (75%) and 2011 AH MC31 (%)

39. The major product in the reaction of HCl with 2-methylpent-2-ene,



is

A 2-chloro-2-methylpentane

B 3-chloro-2-methylpentane

C 2,3-dichloro-2-methylpentane

D 4-chloro-4-methylpentane.

2014 revAH MC25 (89%)

25. Which of the following is **not** an example of a hydrolysis reaction?

A $C_2H_4 + H_2O \rightarrow C_2H_5OH$

B $CH_3CN + 2H_2O \rightarrow CH_3COOH + NH_3$

C $CH_3COOCH_3 + H_2O \rightarrow CH_3COOH + CH_3OH$

D $C_6H_5COOCH_3 + H_2O \rightarrow C_6H_5COOH + CH_3OH$

2002 AH MC28 (44%)

28. 0·5 mol of an organic compound, X, required 24 litres of hydrogen for complete hydrogenation.

Assuming the molar volume of hydrogen to be 24 litres mol^{-1} under the reaction conditions, X could be

A $CH_3C \equiv CH$

B CH_3CH_2CHO

C $HC \equiv CCH_2CH = CH_2$

D $CH_3CH = CHCH_2OH$.

2003 AH MC30 (57%)

30. Which of the following is **not** caused by hydrogen bonding?

A The higher melting points of fats compared to those of oils

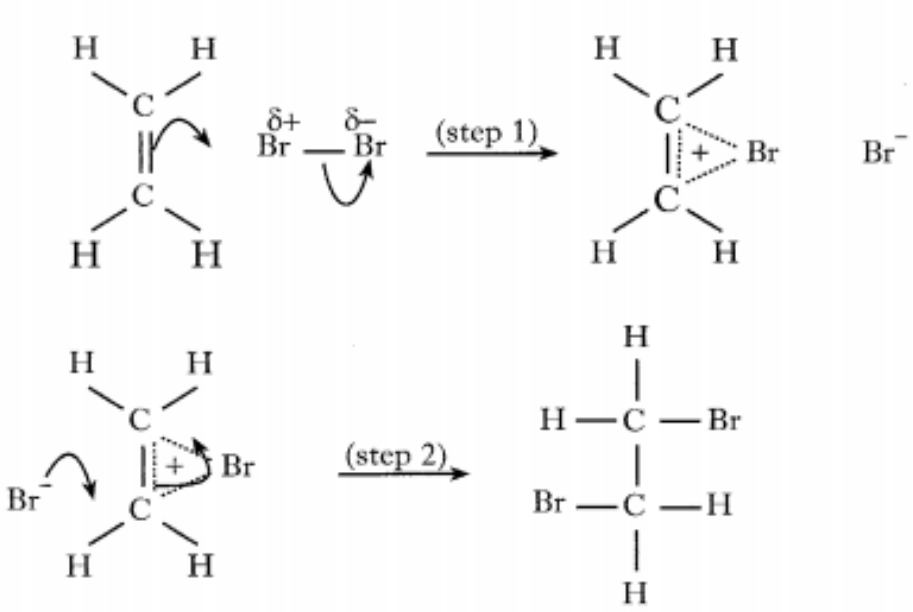
B The formation of dimers in pure ethanoic acid

C The higher boiling point of methanol compared with that of ethane

D The miscibility of propanone with water

2002 AH MC30 (48%) and 2008 AH MC24 (51%) and 2015 AH MC30 (62%)

30.



The two steps in the reaction mechanism shown can be described as

A ethene acting as a nucleophile and Br^- acting as an electrophile

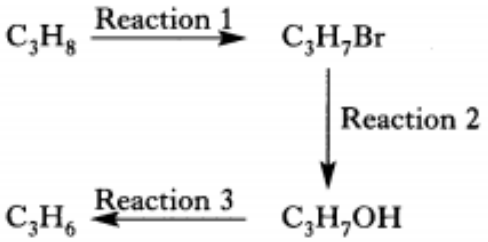
B ethene acting as an electrophile and Br^- acting as a nucleophile

C ethene acting as a nucleophile and Br^- acting as a nucleophile

D ethene acting as an electrophile and Br^- acting as an electrophile.

2006 AH MC26 (85%)

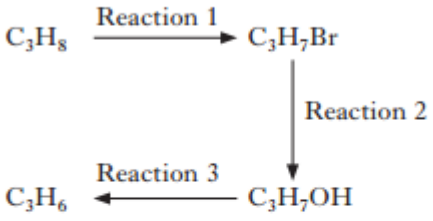
26. **Which line in the table correctly describes the types of reaction in the following sequence?**



	Reaction 1	Reaction 2	Reaction 3
A	addition	substitution	dehydration
B	addition	addition	condensation
C	substitution	substitution	dehydration
D	substitution	addition	condensation

2015 AH MC28 (81%)

28. Which line in the table correctly describes the types of reaction in the following sequence?



	Reaction 1	Reaction 2	Reaction 3
A	addition	substitution	elimination
B	addition	addition	condensation
C	substitution	substitution	elimination
D	substitution	addition	condensation

2005 AH MC35 (66%) and 2016 AH MC19 (73%)

35. When but-1-ene reacts with hydrogen chloride, 1-chlorobutane and 2-chlorobutane are formed. According to Markovnikov's rule

A there will be more of the 2-chlorobutane than the 1-chlorobutane

B there will be more of the 1-chlorobutane than the 2-chlorobutane

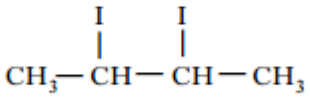
C there will be equal proportions of both products

D it is impossible to tell the relative proportion of each product.

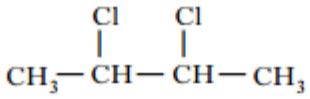
2009 AH MC27 (59%)

27. When but-2-ene is shaken with an aqueous solution of chlorine in potassium iodide, the structural formula(e) of the product(s) is/are

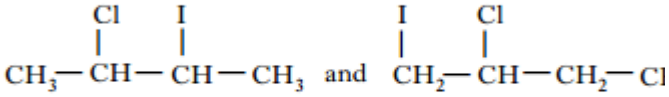
A



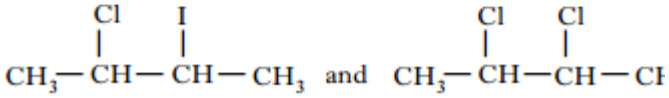
B



C



D



2012 AH MC28 (78%)

28. Which of the following is correct for the reaction of propene with hydrogen bromide?

A 1-Bromopropane is the only product.

B 1-Bromopropane is the major product.

C 2-Bromopropane is the only product.

D 2-Bromopropane is the major product.

2006 AH MC27 (60%)

27. When ethene reacts with bromine in the presence of potassium chloride, CH_2BrCH_2Cl and CH_2BrCH_2Br are both formed. The first of these two compounds is produced because chloride ions

A compete with ethene to form an ionic intermediate

B compete with bromide ions in attacking a cyclic ion intermediate

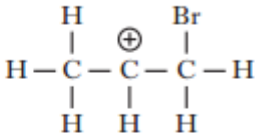
C attack the CH_2BrCH_2Br which had originally formed, displacing the less reactive bromide ions

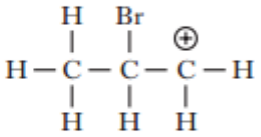
D react with bromine to give chlorine which then attacks the ethene.

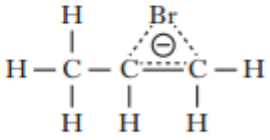
2013 AH MC31 (79%) and 2013 revAH MC24 (73%)

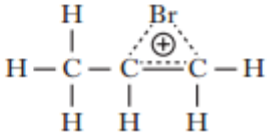
31. Bromine reacts with propene to produce 1,2-dibromopropane.

A possible intermediate in the reaction is

A 

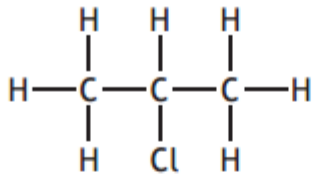
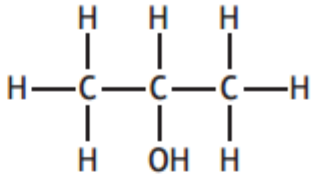
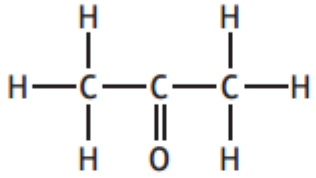
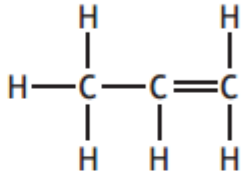
B 

C 

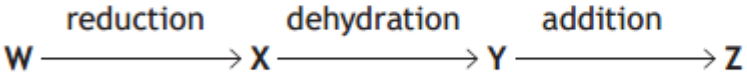
D 

2016 AH MC21 (95%)

21.

 1	 2
 3	 4

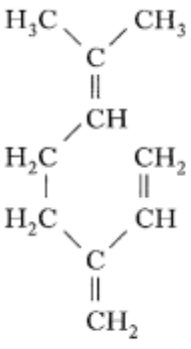
Which line in the table correctly identifies **W**, **X**, **Y** and **Z** in the reaction sequence?



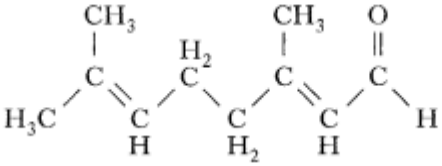
	W	*X*	*Y*	*Z*
A	1	4	2	3
B	3	2	1	4
C	3	2	4	1
D	4	1	2	3

2002 AH L12a+c

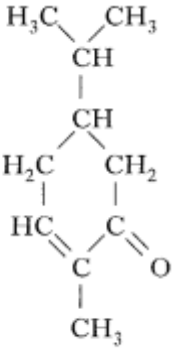
12. Myrcene, citral and carvone belong to a large group of compounds known as terpenes.



myrcene



citral



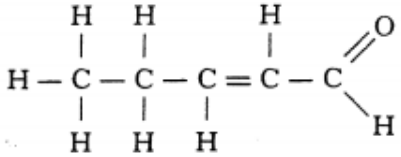
carvone

(*a*) The molecular unit from which terpenes are synthesised is 2-methylbuta-1,3-diene.
Draw the structural formula of 2-methylbuta-1,3-diene. **1**

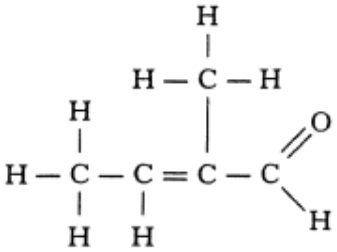
(*c*) Myrcene undergoes addition with excess hydrogen bromide. Assuming that the addition follows Markovnikov's rule, draw the structural formula of the product. **1**

2001 AH L10c

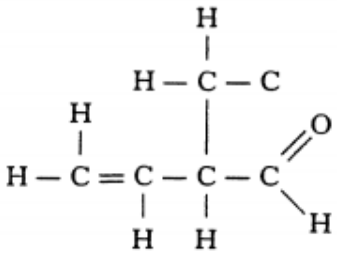
10. An unsaturated aldehyde has the molecular formula C_5H_8O. The formulae of three of its structural isomers are drawn below.



A

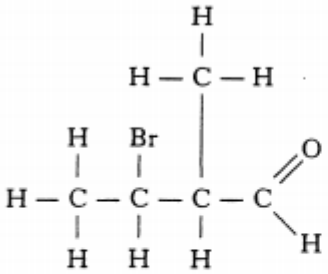


B

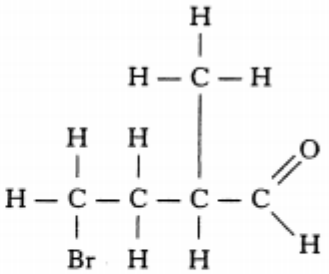


C

(*c*) On treating compound **C** with hydrogen bromide two products, **D** and **E**, are formed.



D



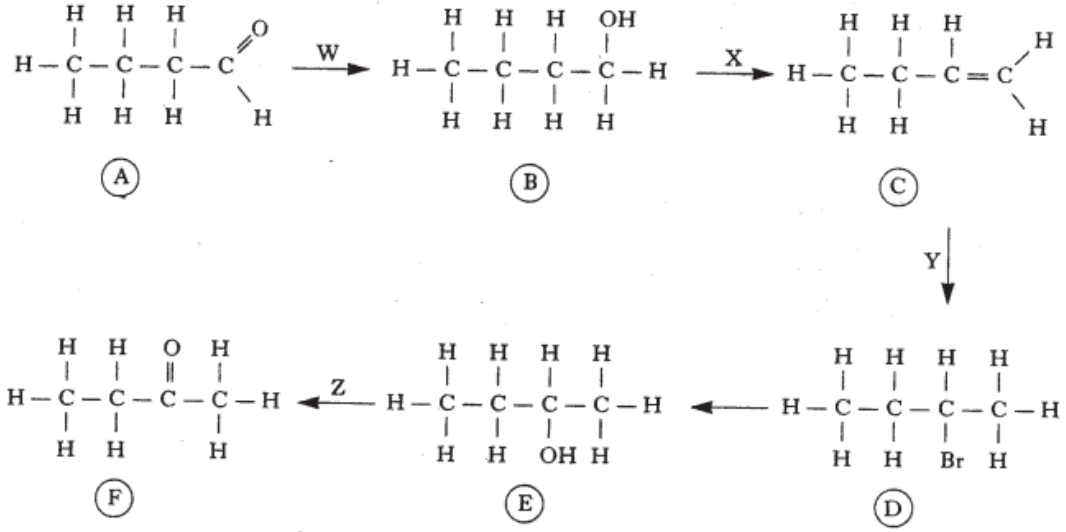
E

(i) Outline the mechanism for the formation of **D**. **2**

(ii) According to Markovnikov's rule which of the two products is formed in greater yield? **1**

2003 AH L5b(i) + 5c

5. A student designed the following reaction sequence.



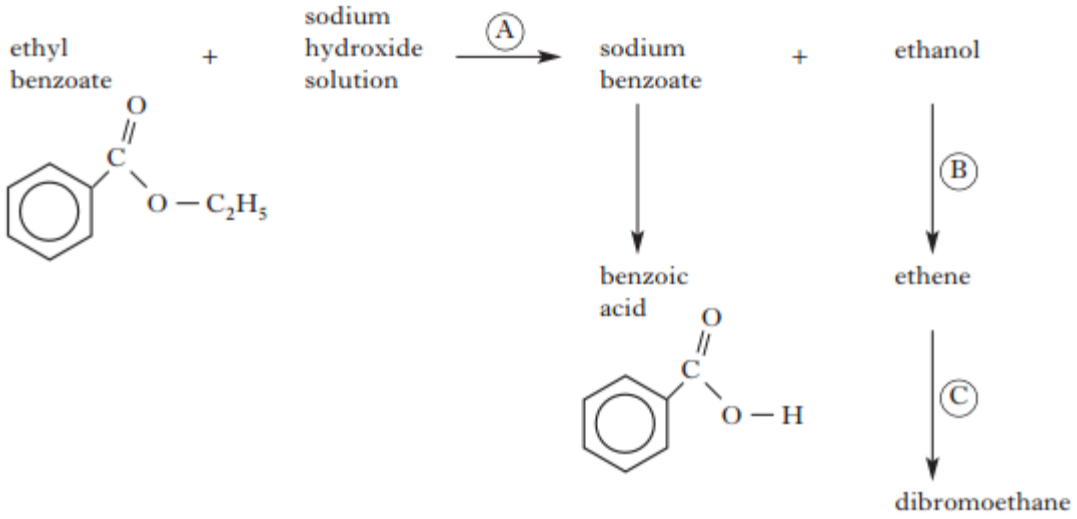
(*b*) What type of reaction occurs at

(i) step **X**

(*c*) Name the other product which is likely to be formed in step Y. **1**

2007 AH L12b(ii)

12. A student designed the following reaction scheme starting from ethyl benzoate.



(*b*)

(ii) Using structural formulae, outline the mechanism for the reaction occurring in step (C). **2**

2008 AH L10c

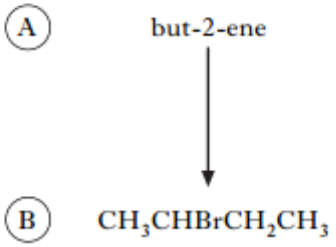
10. A mixture of butan-1-ol and butan-2-ol can be synthesised from 1-bromobutane in a two stage process.

$$CH_3CH_2CH_2CH_2Br \xrightarrow[\textbf{Stage 1}]{KOH/C_2H_5OH} CH_3CH_2CH{=}CH_2 \xrightarrow[\textbf{Stage 2}]{H_2O/H^+} \text{butan-1-ol} + \text{butan-2-ol}$$

(*c*) Draw a structural formula for the major product of **Stage 2**. **1**

2010 AH L11b

11. Consider the following reaction scheme.



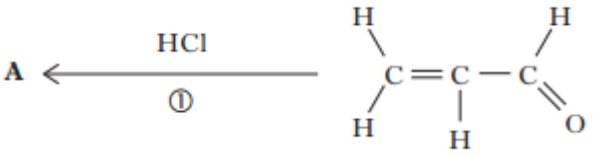
(*b*) But-2-ene undergoes electrophilic addition to form (B).

Draw a structure for the carbocation intermediate formed in this electrophilic addition reaction. **1**

2014 AH L7b(i) and 2014 revAH L8b(i)

7. Methanal is the simplest aldehyde and propenal is the simplest unsaturated aldehyde.

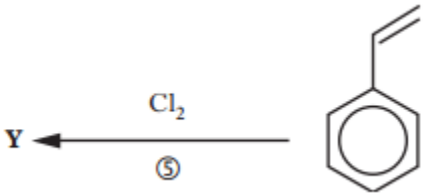
(*b*) Some possible reactions of propenal are shown below.



(i) Draw a structural formula for compound **A**. **1**

2013 revAH L10e

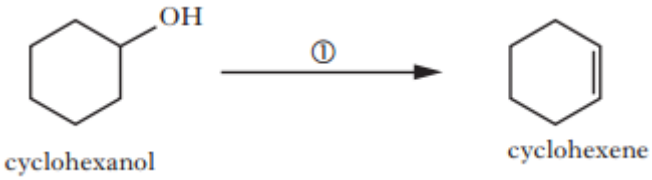
10. A student devised the following reaction sequence.



(*e*) Draw a structural formula for product **Y**. **1**

2013 revAH L11a

11. Cyclohexanol can be converted into cyclohexene or cyclohexanone using different reagents as outlined below.



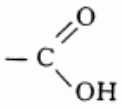
(*a*) Suggest a dehydrating agent that could be used to convert cyclohexanol into cyclohexene in reaction ①. **1**

AH Exercise 2.3e

Carboxylic Acids

2001 AH MC28 (61%) and 2014 AH MC31 (54%) and 2014 revAH MC22 (55%)

28. Select the statement which is true about the carboxyl group



A The C = O and —OH groups each retain their own properties, unaffected by the other.

B The properties of the C = O are changed but the —OH is unaffected.

C The properties of the —OH are changed but the C = O is unaffected.

D The properties of the C = O and the —OH are each affected by the other.

2006 AH MC33 (65%)

33. Which of the following can be oxidised by Tollens' reagent?

A CH_3COCH_3

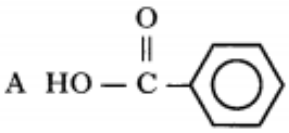
B CH_3CHO

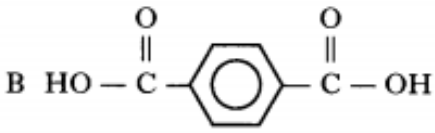
C CH_3OH

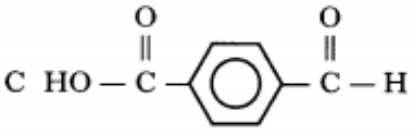
D $(CH_3)_2CHOH$

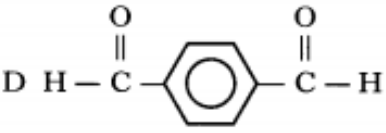
2006 AH MC32 (73%)

32. Which of the following, when reacted with ethane-1,2-diol, would form a polyester?

A 

B 

C 

D 

2005 AH MC26 (79%)

26. The type of reaction involved in the conversion of propanoic acid into propan-1-ol is

A elimination

B substitution

C oxidation

D reduction.

2013 AH MC29 (82%) and 2013 revAH MC22 (87%)

29. The conversion of butanoic acid into butan-1-ol is an example of

A elimination

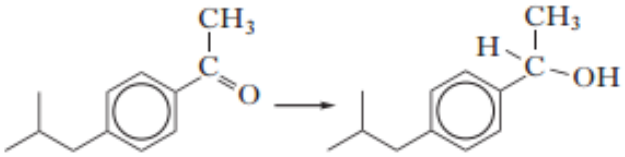
B substitution

C oxidation

D reduction.

2015 revAH MC16 (83%)

16. One of the stages in the preparation of Ibuprofen is shown.



Which of the following reagents could bring about this change?

A HCl

B $LiAlH_4$

C HCN

D H_2O

2005 AH MC37 (63%) and 2011 AH MC32 (67%) and 2015 AH MC32 (40%)

37. A compound, **X**, reacts with the product of its own oxidation to form an ester.
X could be

A propanal

B propan–1–ol

C propan–2–ol

D propanoic acid.

2004 AH MC36 (33%)

36. What would be the products formed when $CH_3COOCH_2CH_2OOCCH_3$ is warmed with aqueous sodium hydroxide solution?

A $CH_3COONa + HOCH_2CH_2OH$

B $CH_3COOH + NaOCH_2CH_2ONa$

C $CH_3COONa + C_2H_5OOCCH_3$

D $CH_3COOCH_3 + H_2O$

2008 AH MC32 (63%)

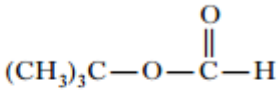
32. Two isomeric esters, **X** and **Y**, have the molecular formula $C_4H_8O_2$. Ester **X** on hydrolysis with sodium hydroxide solution gives CH_3CH_2COONa, and ester **Y** on similar treatment gives CH_3CH_2OH.

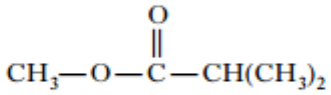
Which line in the table shows the correct names of **X** and **Y**?

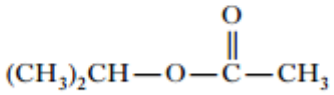
	X	Y
A	propyl methanoate	ethyl ethanoate
B	methyl propanoate	ethyl ethanoate
C	methyl propanoate	ethyl methanoate
D	propyl methanoate	methyl propanoate

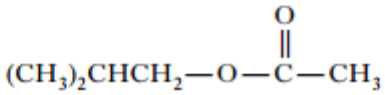
2009 AH MC30 (68%)

30. Which of the following esters gives a secondary alcohol when hydrolysed?

A 

B 

C 

D 

2009 AH MC32 (35%)

32. Which of the following will react with dilute sodium hydroxide solution?

A $CH_3CHOHCH_3$

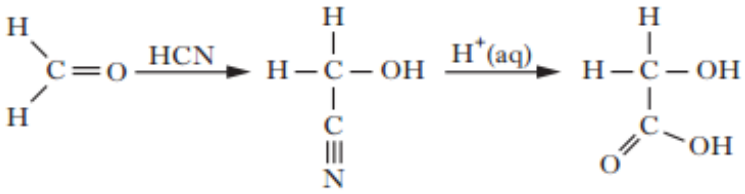
B $CH_3CH{=}CH_2$

C CH_3COOCH_3

D $CH_3CH_2OCH_3$

2013 revAH MC30 (50%)

30. Carbonyl groups in aldehydes and ketones react with HCN and the product can then be hydrolysed forming a 2-hydroxycarboxylic acid as shown in the equation below.



methanal 2-hydroxyethanoic acid

When the final product is 2-hydroxy,2-methylbutanoic acid, the starting carbonyl compound is

A propanal

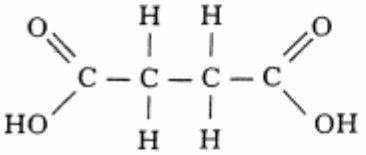
B propanone

C butanal

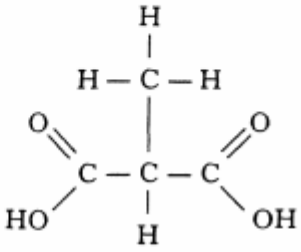
D butanone.

2001 AH L11a

11. The structures of the two dicarboxylic acids with molecular formula $C_4H_6O_4$ are drawn below.



A

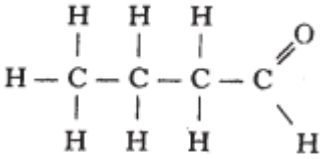


B

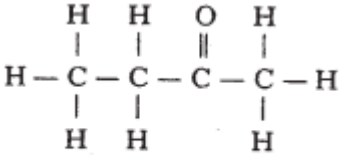
(*a*) **A** is called butanedioic acid.
Name **B**. **1**

2003 AH L5d

5. A student designed the following reaction sequence.



(A)



(F)

(*d*) Name a reagent which could be used to distinguish between (A) and (F). **1**

2007 AH L10

10. Isoamyl acetate is found naturally as the flavour and scent of bananas.
Its shortened structural formula is

$$CH_3COOCH_2CH_2CH(CH_3)_2$$

(*a*) (i) To which class of organic compounds does isoamyl acetate belong? **1**

(ii) Apart from flavouring agents, suggest another common use for this class of organic compound. **1**

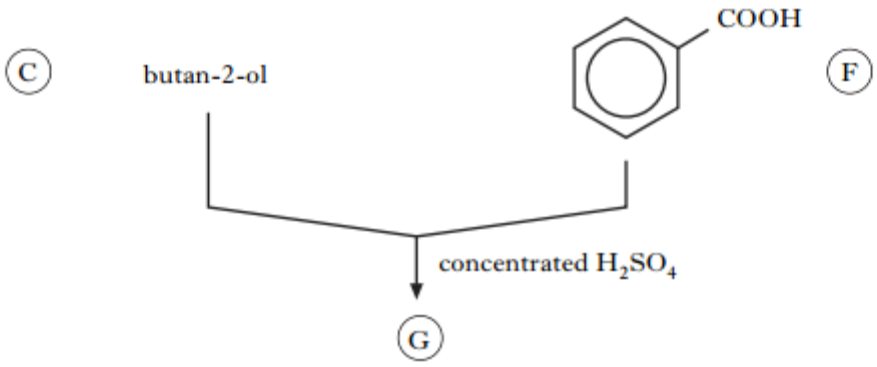
Isoamyl acetate can be made in the laboratory by reacting ethanoic acid with another substance, **X**.

(*b*) (i) Write the systematic name of substance **X**. **1**

(ii) Name the type of reaction which takes place. **1**

2010 AH L11e

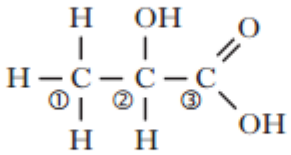
11. Consider the following reaction scheme.



(*e*) Draw a structural formula for ester (G). **1**

2011 AH L14a

14. The structure of lactic acid is



(*a*) What is the systematic name of lactic acid? **1**

2012 AH L11b

11. Both lithium aluminium hydride, $LiAlH_4$, and phosphorus pentachloride, PCl_5, react vigorously with water producing different gases.

(*b*) Phosphorus pentachloride will also react with any compound containing a hydroxyl group. A chlorine atom replaces the hydroxyl group. For example,

$$C_6H_5COOH \xrightarrow{PCl_5} C_6H_5COCl \quad \text{or} \quad CH_3COOH \xrightarrow{PCl_5} CH_3COCl$$

(i) What type of organic compound is produced in these reactions? **1**

(ii) Draw a structural formula for the ester formed when C_6H_5COCl reacts with propan-2-ol. **1**

(iii) What is the advantage of using C_6H_5COCl instead of benzoic acid in this esterification reaction? **1**

2014 AH L5a and 2014 revAH L2a

2. The dicarboxylic acid, oxalic acid, has molecular formula $H_2C_2O_4$.

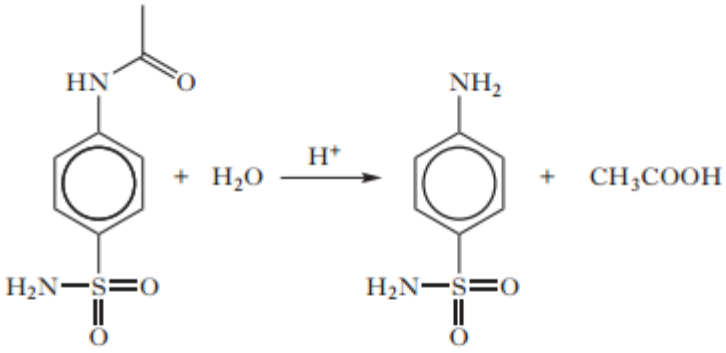
It can be prepared by reacting calcium oxalate with sulfuric acid.

$$H_2SO_4(aq) + CaC_2O_4(s) + xH_2O(\ell) \rightarrow CaSO_4.xH_2O(s) + H_2C_2O_4(aq)$$

(*a*) Draw a structural formula for oxalic acid. **1**

4. Sulfa drugs are compounds with antibiotic properties. Sulfa drugs can be prepared from a solid compound called sulfanilamide.

Sulfanilamide is prepared in a six stage synthesis. The equation for the final step in the synthesis is shown.



$C_8H_{10}N_2SO_3$ $C_6H_8N_2SO_2$

4-acetamidobenzenesulfonamide sulfanilamide

(*a*) What type of reaction is this? **1**

AH Exercise 2.3f

Amines

2016 AH MC15 (67%)

15. In the homologous series of amines, an increase in chain length is accompanied by

	Volatility	*Solubility in water*
A	increased	increased
B	decreased	decreased
C	increased	decreased
D	decreased	increased

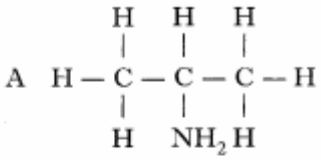
2001 AH MC25 (83%) and 2007 AH MC30 (74%)

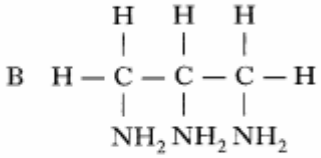
25. In the homologous series of amines, increase in chain length from CH_3NH_2 to $C_4H_9NH_2$ is accompanied by

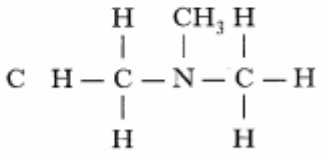
	Volatility	Solubility in water
A	increased	increased
B	decreased	decreased
C	increased	decreased
D	decreased	increased

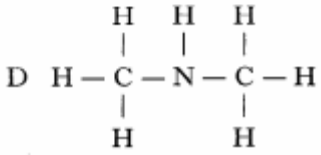
2002 AH MC5 (80%) and 2014 revAH MC24 (90%)

5. Which of the following structures represents a tertiary amine?

A 

B 

C 

D 

2003 AH MC28 (53%) and 2007 AH MC26 (61%) and 2008 AH MC34 (65%)

28. Which of the following amines has the lowest boiling point?

A $C_4H_9NH_2$

B $C_3H_7NHCH_3$

C $C_2H_5NHC_2H_5$

D $C_2H_5N(CH_3)_2$

2011 AH MC33 (89%)

33. Which of the following amines does **not** have hydrogen bonds between its molecules in the liquid state?

A $CH_3CH_2CH_2CH_2NH_2$

B $CH_3CH_2NHCH_2CH_3$

C $(CH_3)_2CHCH_2NH_2$

D $(CH_3)_2NCH_2CH_3$

2008 AH MC33 (57%)

33. A white crystalline compound, soluble in water, was found to react with both dilute hydrochloric acid and sodium hydroxide solution.

Which of the following might it have been?

A C_6H_5OH

B $C_6H_5NH_2$

C C_6H_5COOH

D H_2NCH_2COOH

2009 AH MC34 (65%)

34. Which of the following compounds is soluble in water and reacts with both dilute hydrochloric acid and sodium hydroxide solution?

A $C_2H_5NH_2$

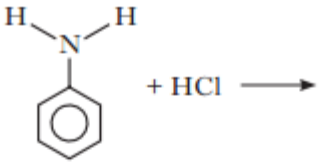
B $C_6H_5NH_2$

C $C_2H_5NH_3Cl$

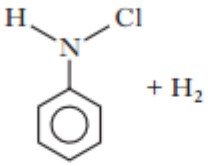
D $HOOCCH_2NH_2$

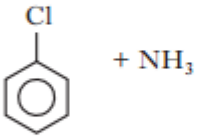
2013 AH MC37 (28%)

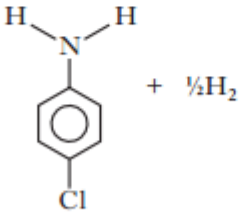
37. Phenylamine reacts with hydrochloric acid.

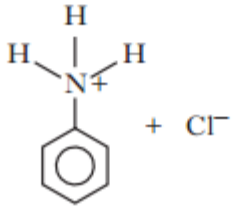


The products are

A 

B 

C 

D 

2003 AH MC27 (40%)

27. A white crystalline compound, soluble in water, was found to react with both dilute hydrochloric acid and sodium hydroxide solution. Which of the following might it have been?

A Aminobenzene

B Aminoethanoic acid

C Ethylamine

D Ethylammonium chloride

2004 AH MC37 (80%)

37. Which of the following compounds would dissolve in water to give an alkaline solution?

A CH_3COCH_3

B CH_3CH_2CN

C CH_3CH_2CHO

D $CH_3CH_2NH_2$

2012 AH MC34 (82%)

34. Which of the following compounds would dissolve in water to give an alkaline solution?

A CH_3CH_2CN

B CH_3CH_2CHO

C $CH_3CH_2CH_2OH$

D $CH_3CH_2CH_2NH_2$

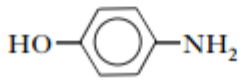
2011 AH MC34 (41%)

34. 1 mole of which of the following compounds would react with the largest volume of 1 mol l^{-1} hydrochloric acid?

A CH_3NHCH_3

B $H_2NCH_2NH_2$

C $CH_2OHCHOHCH_2OH$

D 

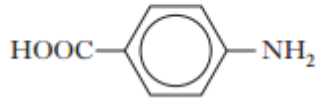
2014 AH MC34 (62%)

23. One mole of which of the following compounds will react with the largest volume of 1 mol l^{-1} hydrochloric acid?

A CH_3NHCH_3

B $H_2NCH_2NH_2$

C $HOOCCH_2NH_2$

D 

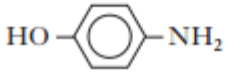
2014 revAH MC23 (63%)

34. One mole of which of the following compounds will react with the largest volume of 1 mol l^{-1} hydrochloric acid?

A CH_3NHCH_3

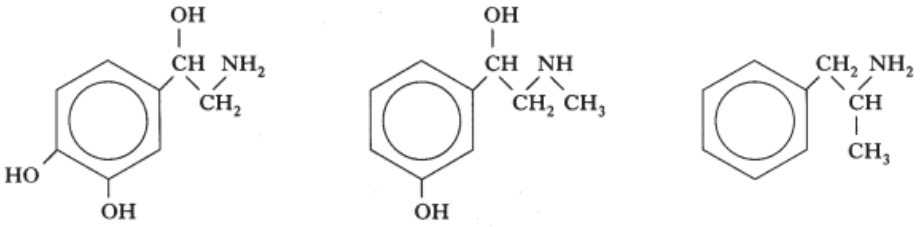
B $H_2NCH_2NH_2$

C $HOOCCH_2NH_2$

D 

2004 AH L11c

11. The three molecules shown below can all increase blood pressure if introduced into the human body.



noradrenaline phenylephrine amphetamine

(*c*) Amines can be classified as primary, secondary or tertiary. To which class of amine does phenylephrine belong? **1**

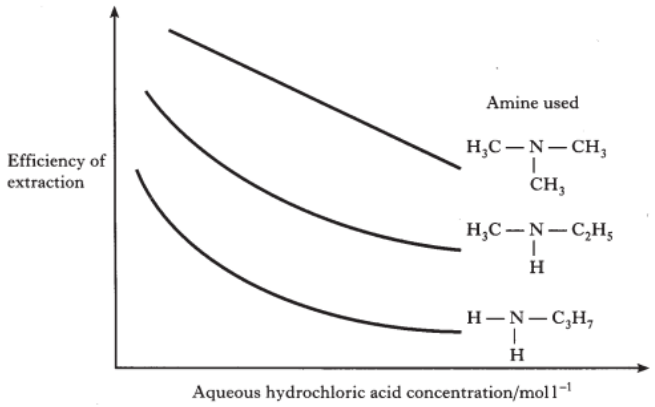
2005 AH L5b

5. Solvent extraction is a technique used in the extraction of platinum from its ore. This extraction makes use of the fact that platinum complexes have different solubilities in aqueous hydrochloric acid and in organic solvents.

(*b*) The organic solvents used to extract platinum contain an amine.

There are three types of amine, primary, secondary and tertiary.

The diagram shows how three amines affect the partition coefficient at different concentrations of hydrochloric acid.

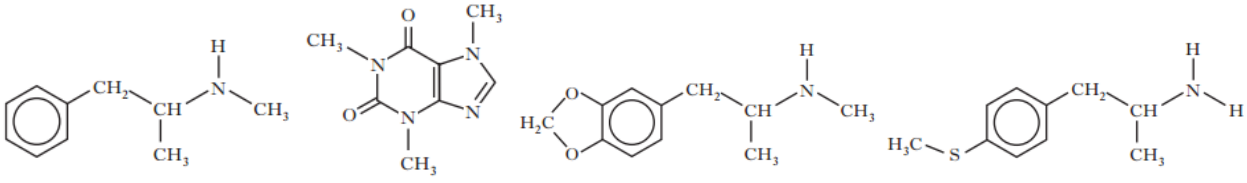


Which **type** of amine is most efficient at extracting $[PtCl_6]^{2-}$? **1**

2012 AH L11a+b

11. Methylamphetamine (also known as "speed") and caffeine are stimulants.

A "designer drug" with a structure related to methylamphetamine is ecstasy. Ecstasy tablets are sometimes contaminated with a substance called 4-MTA.



methylamphetamine caffeine ecstasy 4-MTA

(*a*) Caffeine contains more than one "amide" functional group.

Draw the structure of caffeine and circle **one** of the "amide" functional groups. **1**

(*b*) Which of the four molecules contains a primary amine functional group? **1**

AH Exercise 2.3G

Aromatics

2016 AH MC22 (68%)

22. Which of the following statements about benzene is **not** true?

A It is planar.
B It is susceptible to attack by electrophilic reagents.
C Its carbon to carbon bonds are equal in length.
D It is readily attacked by bromine.

2005 AH MC40 (55%)

40. CH═CHCOOH

The above compound should **not** react with

A ethanol
B bromine water
C copper(II) oxide
D a mixture of concentrated nitric and sulphuric acids.

2010 AH MC30 (49%)

30. Caryophyllene ($C_{15}H_{24}$) is an unsaturated cyclic hydrocarbon.

Complete hydrogenation of caryophyllene gives a saturated hydrocarbon $C_{15}H_{28}$.

Which line in the table shows the correct numbers of double bonds and rings in caryophyllene?

	Number of double bonds	Number of rings
A	2	1
B	2	2
C	4	2
D	4	4

2004 AH MC38 (42%) and 2009 AH MC33 (57%)

38. Which of the following molecules is planar?

A Chlorobenzene
B Methylbenzene (toluene)
C Cyclohexane
D Hexane

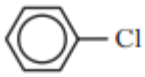
2010 AH MC37 (64%)

37. Which of the following statements about the benzene molecule is **not** true?

A It is planar.
B It has empirical formula CH.
C It is readily attacked by bromine.
D Its C—C bonds are equal in length.

2012 AH MC31 (20%)

31. **P**



Q CH_2=CHCl

R CH_2=CHCH$_2$Cl

Which of the above molecules is/are planar?

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

2013 AH MC39 (50%) and 2013 revAH MC28 (56%)

39.

The above reaction is an example of

A addition
B oxidation
C elimination
D substitution.

2001 AH MC15 (50%) and 2011 AH MC35 (72%)

15. The conversion of benzene to monochlorobenzene using $Cl_2/FeCl_3$ involves

A nucleophilic addition

B nucleophilic substitution

C electrophilic addition

D electrophilic substitution.

2003 AH MC33 (42%)

33. Which halide will be most resistant to attack by nucleophilic reagents?

A CH_3CH_2Br

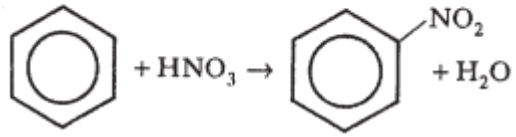
B C_6H_5Br

C $(CH_3)_3CCl$

D $(CH_3)_2CHCl$

2003 AH MC37 (70%)

37. In the reaction between benzene and nitric acid in the presence of concentrated sulphuric acid



A the benzene molecule acts as an electrophile

B the ion, NO_3^-, acts as a nucleophile

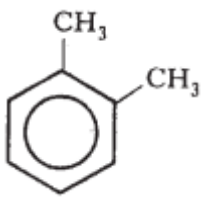
C the ion, NO_2^+, acts as an electrophile

D the HNO_3 is oxidised.

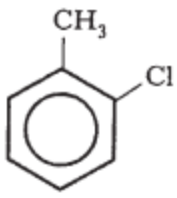
2003 AH MC38 (37%)

38. Which of the following will be produced when methylbenzene is reacted with chloromethane in the presence of aluminium chloride?

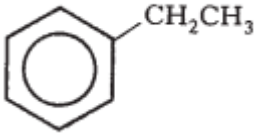
A



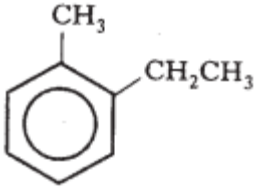
B



C



D



2007 AH MC27 (70%)

27. Chlorobenzene, nitrobenzene and ethylbenzene can all be formed from benzene by

A electrophilic substitution

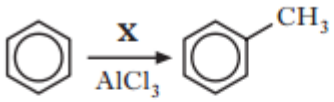
B electrophilic addition

C nucleophilic substitution

D nucleophilic addition.

2012 AH MC35 (68%)

35.



Which of the following compounds could be **X**?

A CH_4

B CH_3Cl

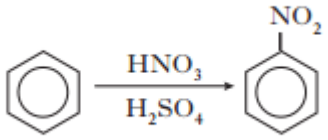
C CH_2Cl_2

D CH_3OH

2011 AH MC36 (51%)

2013 AH MC38 (61%) and 2013 revAH MC27 (63%)

36.



Which species initially attacks the benzene molecule in the above reaction?

A NO_3^-

B NO_2^+

C HSO_4^-

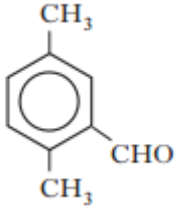
D NO_2

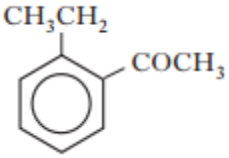
2007 AH MC38 (68%) and 2008 AH MC35 (71%)

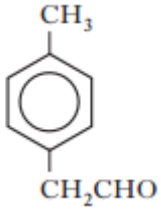
38. Spectral studies of an organic compound indicated the presence of a di-substituted benzene ring, two methyl groups and a molecular weight of 134.

Which of the following is a possible structure for the compound?

A 

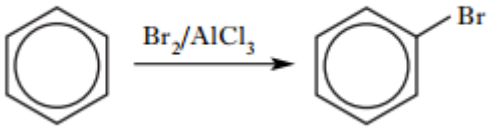
B 

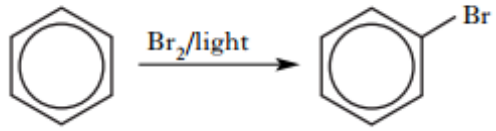
C 

D 

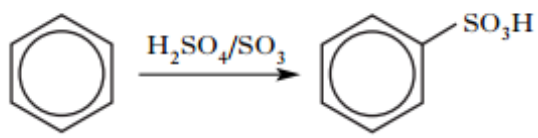
2009 AH MC35 (41%)

35. Which of the following reactions is least likely to take place?

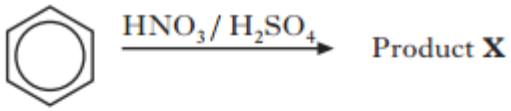
A 

B 

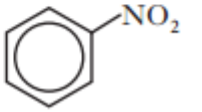
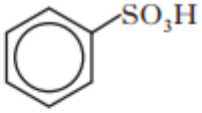
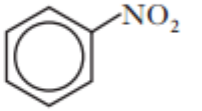
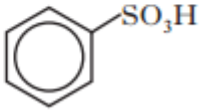
C 

D 

2010 AH MC36 (69%)

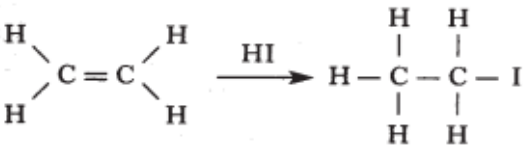
36. 

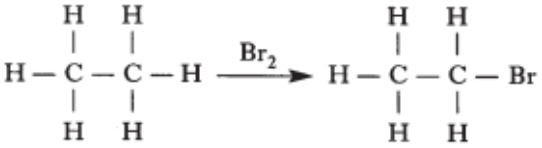
Which line in the table is correct for the reaction above?

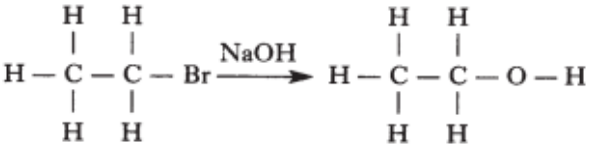
	Type of reaction	Product **X**
A	electrophilic substitution	
B	electrophilic substitution	
C	nucleophilic substitution	
D	nucleophilic substitution	

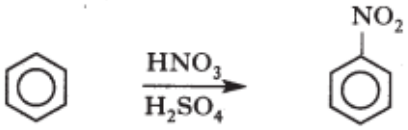
2004 AH MC30 (66%)

30. Which of the following involves electrophilic substitution?

A 

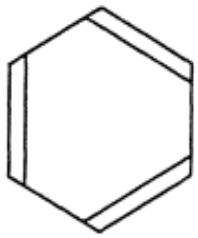
B 

C 

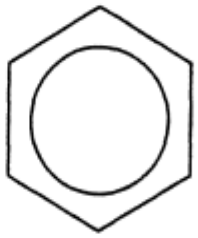
D 

2001 AH L5a+5c

5. The molecule benzene, formula C_6H_6, has been described as involving alternating single and double carbon to carbon bonds as in diagram **A**. Diagram **B** is generally regarded as giving a more valid view of the structure.



A



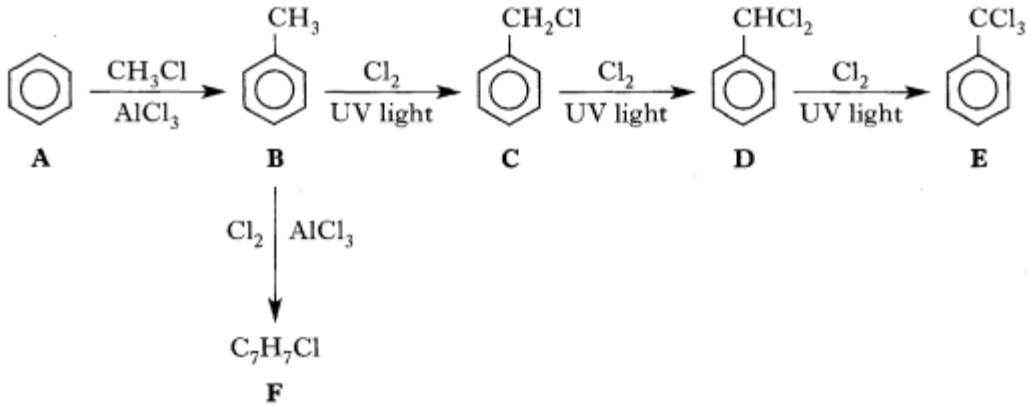
B

(*a*) Give **one** other piece of evidence which contradicts structure **A**. **1**

(*c*) What feature of the bonding accounts for the relative stability of structure **B**? **1**

2002 AH L6a+b

6. Consider the following reaction sequence.

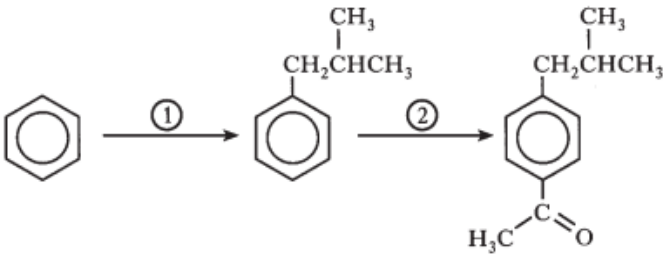


(*a*) Name the type of substitution reaction taking place in the conversion of **A** into **B** and **B** into **F**. **1**

(*b*) **F** is a mixture of three isomers. Draw the structural formula of one of these isomers. **1**

2005 AH L10

10. Ibuprofen is an anti-inflammatory agent which can be synthesised from benzene as shown below.

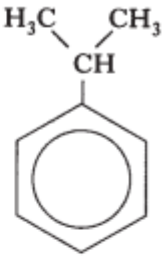


(*a*) Name the type of reaction taking place in steps ① and ②. **1**

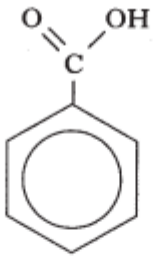
2004 AH L4

4. The structural formulae of three aromatic compounds are shown below.

benzene



2-phenylpropane



benzoic acid

The relative formula masses and boiling points of these compounds are shown in the table below.

Compound	Relative formula mass	Boiling point/°C
benzene	78·1	80
2-phenylpropane	120·2	152
benzoic acid	122·1	250

(*a*) In terms of bonding, why does 2-phenylpropane have a higher boiling point than benzene? **1**

(*b*) Benzoic acid and 2-phenylpropane molecules are of similar size and shape. Why is the boiling point of benzoic acid higher than that of 2-phenylpropane? **1**

(*c*) What would benzene be reacted with to form 2-phenylpropane? **1**

2007 AH L8c

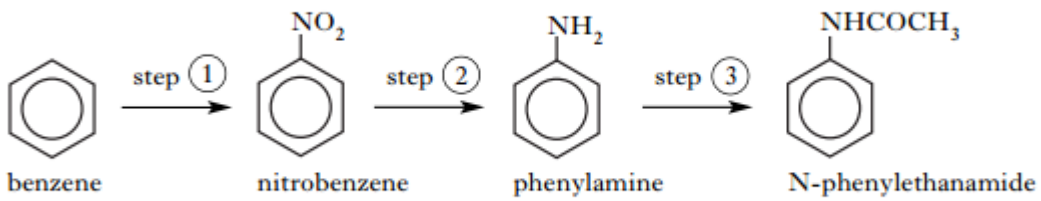
8. The following table gives information about aluminium chloride and magnesium chloride.

	Aluminium chloride	Magnesium chloride
Action of heat	sublimes at 178 °C	melts at 714 °C
Relative formula mass in gaseous state	267	95
Action of water	reacts to give white fumes	dissolves

(*c*) Aluminium chloride can be used as a catalyst in the reaction between benzene and 2-chloropropane. Draw a structure for an organic product formed. **1**

2009 AH L10a

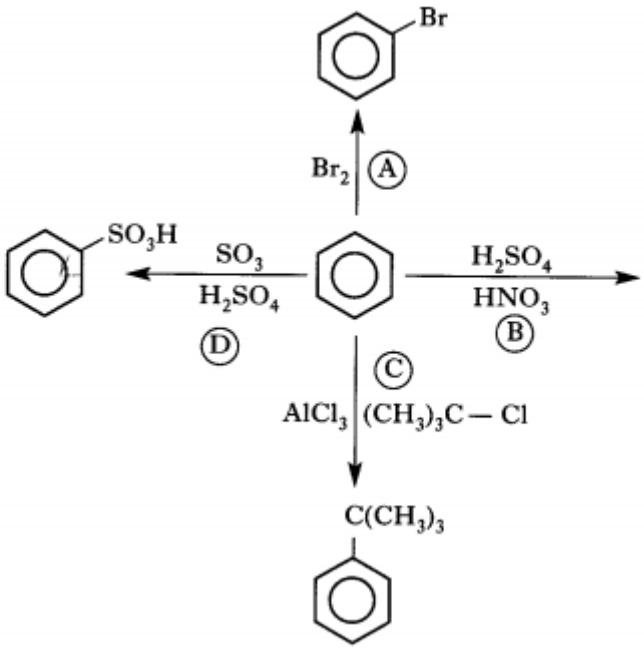
10. N-Phenylethanamide can be prepared from benzene in three steps.



(*a*) What chemicals are required to react with benzene to bring about step (1)? **1**

2006 AH L11

11. **Benzene is one of the most important aromatic feedstocks in the chemical industry.**
Four electrophilic substitution reactions which benzene undergoes are shown.



(*a*) (i) Which catalyst is required to carry out reaction (A)? **1**

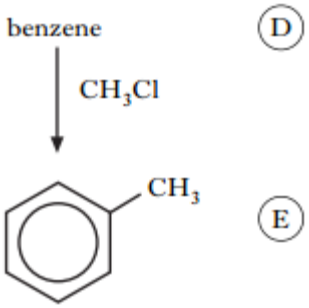
(ii) What is the organic product in reaction (B)? **1**

(iii) The specific name for reaction (C) is alkylation.
What is the specific name for reaction (D)? **1**

(*b*) Both benzene and graphite have delocalised electrons.
Suggest why benzene does not conduct electricity. **1**

2010 AH L11d

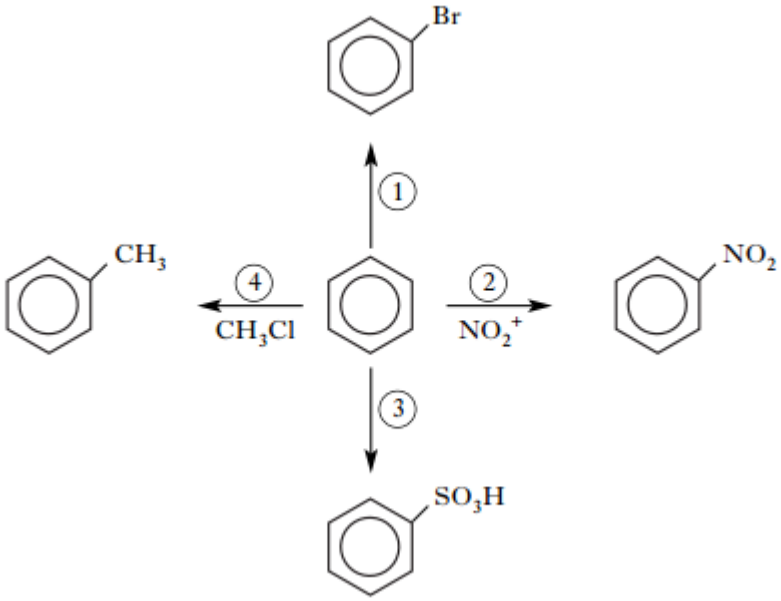
11. Consider the following reaction scheme.



(*d*) Name a catalyst required in converting (D) to (E). **1**

2008 AH L13

13. A student devised the following reaction scheme starting with benzene.



(*a*) What type of reaction does benzene undergo in reactions (1) – (4) ? **1**

(*b*) Name a suitable reagent and catalyst for reaction (1) . **1**

(*c*) Reaction (2) involves nitration of benzene.
Which reagents are used to produce the NO_2^+ ion? **1**

(*d*) What is the molecular formula for the product of reaction (3) ? **1**

(*e*) The product of reaction (4) was reacted with bromine in the presence of light.
Draw a structural formula for an organic product of this reaction. **1**

2012 AH L14a+14b(i)

14. (*a*) Benzene reacts with a "nitrating mixture" to produce nitrobenzene.

(i) Name the type of chemical reaction that takes place in the nitration of benzene. **1**

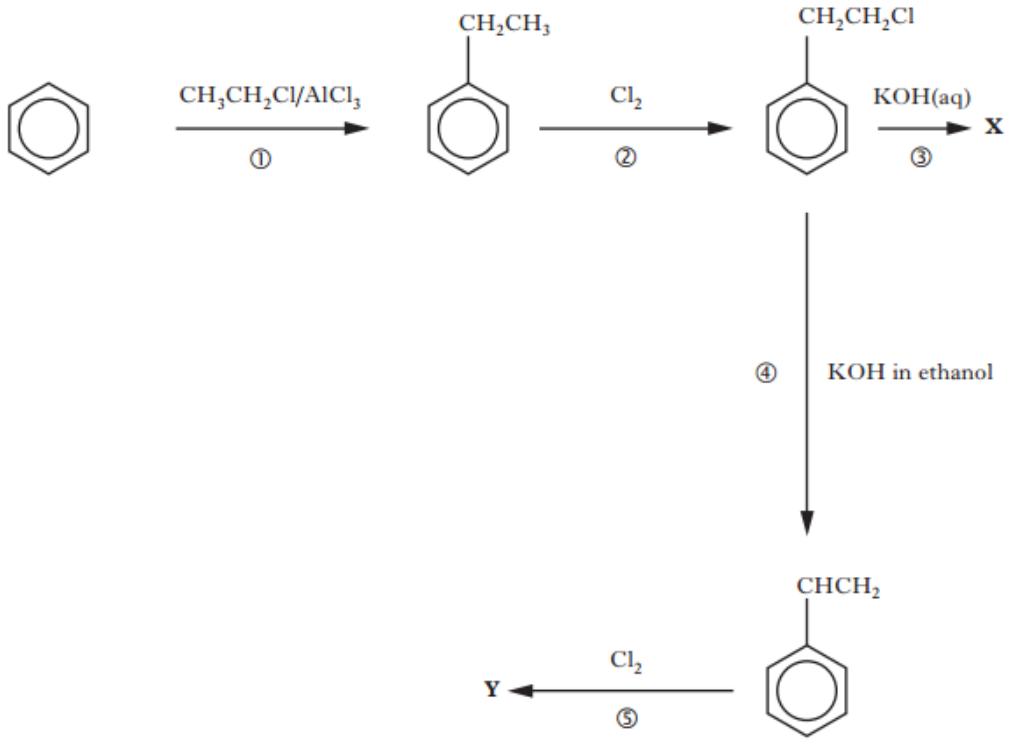
(ii) Nitrobenzene is reduced by reaction with a mixture of tin and concentrated hydrochloric acid to form an organic base.
Identify this organic base. **1**

(*b*) Benzene also reacts with sulphur trioxide dissolved in concentrated sulphuric acid to produce benzenesulphonic acid, $C_6H_5SO_3H$.

(i) Draw a structural formula for benzenesulphonic acid. **1**

2013 AH L10 and 2013 revAH L10

10. A student devised the following reaction sequence.



(*a*) What type of reaction is taking place in step ①? **1**

(*b*) What experimental condition would be required in step ②? **1**

(*c*) Draw a structural formula for product **X**. **1**

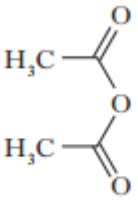
(*d*) What type of reaction is taking place in step ④? **1**

(*e*) Draw a structural formula for product **Y**. **1**

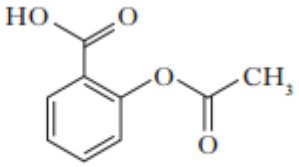
2014 revAH L7b(i)

7. Aspirin is one of the most widely used drugs in our society. Aspirin works as a pain killer by binding to a specific enzyme and blocking its use in biological pathways which lead to the production of pain.

(*b*) Aspirin can be prepared by reacting 2-hydroxybenzoic acid ($C_7H_6O_3$), with ethanoic anhydride in acidic conditions.



ethanoic anhydride

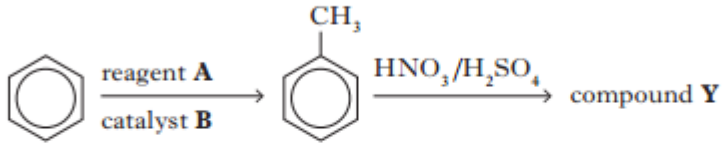


aspirin

(i) Draw a structural formula for 2-hydroxybenzoic acid. **1**

2014 AH L6 and 2014 revAH L6

6. Aromatic compounds are widely used in the production of pigments, antioxidants and agrochemicals. The reaction sequence below starts with benzene.



The first step in the sequence produces methyl benzene.

(*a*) Name reagent **A**. **1**

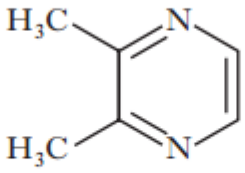
(*b*) Identify catalyst **B**. **1**

(*c*) What name is given to the type of reaction taking place in both steps? **1**

2013 revAH L7a

7. The dominant flavours of chocolate are due to molecules called substituted pyrazines. These are produced when sugars and amino acids react during the roasting of cocoa beans.

An example is 2,3-dimethylpyrazine



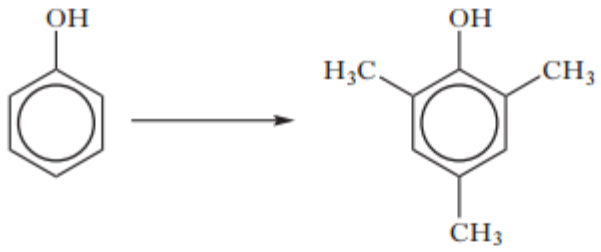
This compound is responsible for the nutty flavour of chocolate. Other substances responsible for the distinctive smell of chocolate are aldehydes including phenylethanal, 2-methylbutanal and 3-methylbutanal.

(*a*) Write the molecular formula for 2,3-dimethylpyrazine. **1**

8. Phenol is an aromatic compound with the following structure.

(*a*) What type of hybridisation do the carbon atoms exhibit in phenol? **1**

(*b*) Phenol takes part in the following reaction.



phenol 2,4,6-trimethylphenol

(i) Suggest a suitable reagent and catalyst for this reaction. **1**

(ii) What type of reaction is taking place? **1**

(*c*) Phenol can be converted into 2,4,6-trinitrophenol using a mixture of concentrated nitric acid and concentrated sulphuric acid.

(i) Draw a structural formula for 2,4,6-trinitrophenol. **1**

(ii) Write the formula of the reactive species acting on phenol in this reaction. **1**