PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

# CHEMISTRY



## EXAM QUESTION PACK

### TOPIC 6: ORGANIC CHEMISTRY I

| SCORE | PERCENTAGE |
| --- | --- |
| /443 | % |

STEMUP

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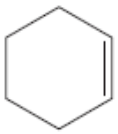
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Q1.

This question is about hydrocarbons.

How many σ bonds and π bonds are there in one molecule of cyclohexene?



**(1)**

| | $\sigma$ bonds | $\pi$ bonds |
|---|---|---|
| ☒ **A** | 5 | 2 |
| ☒ **B** | 6 | 1 |
| ☒ **C** | 15 | 2 |
| ☒ **D** | 16 | 1 |

**(Total for question = 1 mark)**

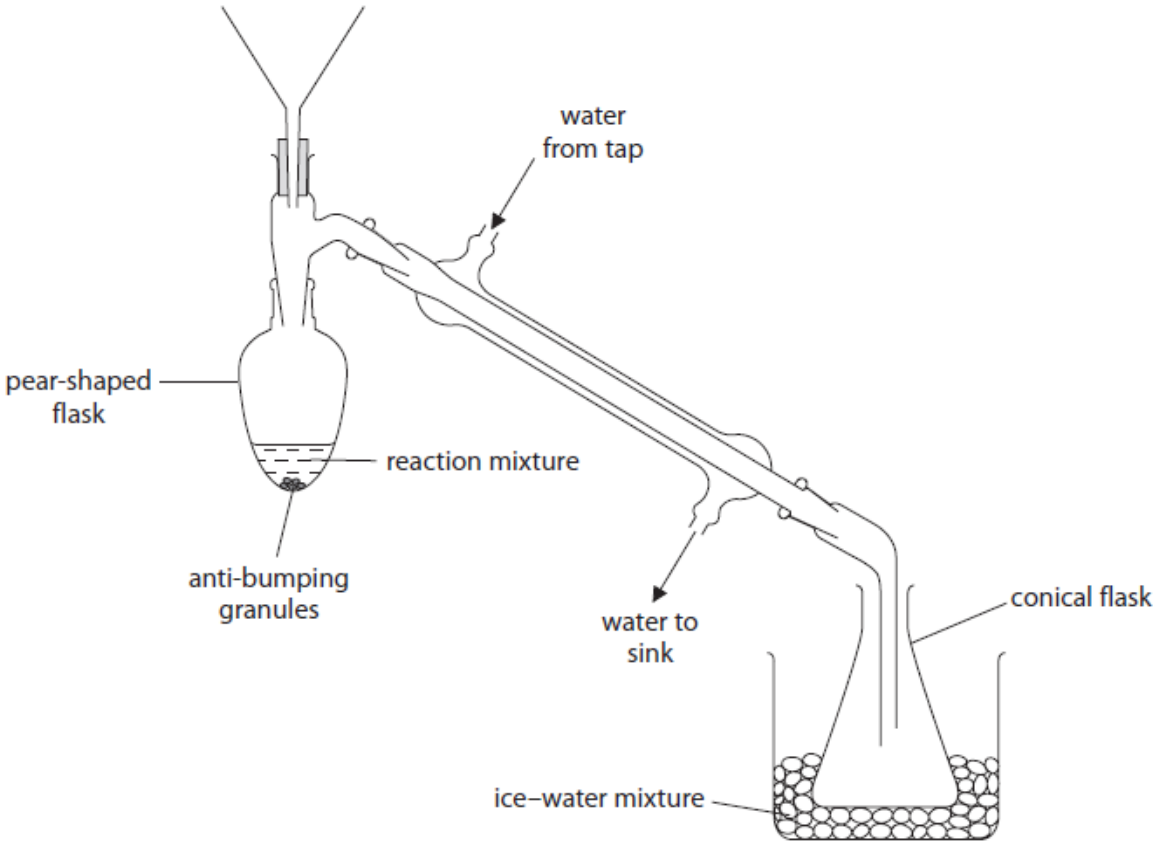
Q2.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.




Once the essential changes are made to the apparatus, the pear-shaped flask is heated. The distillate formed is collected in the conical flask.

On testing the distillate with pH paper, it is found that its pH is 2. The student suggests that this pH is due to the formation of 3-methylbutanoic acid.

(i) Give a reason why 3-methylbutanoic acid cannot be formed in the reaction.

**(1)**

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(ii) Deduce the **formula** of the compound that could cause the distillate to have a pH value of 2.

**(1)**

(iii) Solid sodium carbonate is added to the distillate. The sodium carbonate disappears and fizzing occurs.

Write an equation, including state symbols, for the reaction that occurs between sodium carbonate and the compound you have identified in (ii).

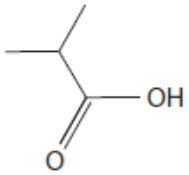
**(2)**

**(Total for question = 4 marks)**

Q3.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

The carboxylic acid shown can be produced by oxidation of an alcohol under reflux.




Which alcohol would be oxidised under reflux to produce this carboxylic acid?

**(1)**

☒ **A** 1,1-dimethylethanol

☒ **B** 2-methylpropan-1-ol

☒ **C** 2-methylbutan-1-ol

☒ **D** propan-2-ol

**(Total for question = 1 mark)**

Q4.

This question is about alkanes and their reactions.

A student researched the reaction of propane with bromine and found that the reaction could be used to make 1-bromopropane.

$$C_3H_8(g) + Br_2(l) \rightarrow C_3H_7Br(l) + HBr(g)$$

(i) The first step of the reaction involves

**(1)**

☒ **A** heterolytic bond fission to form free radicals

☒ **B** heterolytic bond fission to form ions

☒ **C** homolytic bond fission to form free radicals

☒ **D** homolytic bond fission to form ions

(ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (i).

**(2)**

(iii) A source from the internet gave the percentage yield for this reaction as 31.0%.

The best explanation for the low percentage yield of 1-bromopropane in this reaction is

**(1)**

☒ **A** bromine is very unreactive

☒ **B** a gaseous reactant always gives a low yield

☒ **C** the reaction is very slow

☒ **D** the reaction produces a mixture of organic products

(iv) Calculate the volume of propane, in $dm^3$, measured at room temperature and

pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.
Give your answer to an appropriate number of significant figures.

[Molar gas volume at r.t.p. = 24.0 $dm^3$ $mol^{-1}$]

**(3)**

**(Total for question = 7 marks)**

Q5.

This is a question about alkanes.

Alkanes are obtained by processing crude oil.

(i) Explain why different alkanes in crude oil can be separated by fractional distillation.

**(2)**

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(ii) Complete the equation for the cracking of octane to produce ethene and only one other organic compound. State symbols are not required.

**(1)**

$C_8H_{18}$ → ..... + .....

(iii) Write the equation for the reforming of hexane into cyclohexane, using **displayed** formulae for the organic compounds. State symbols are not required.

**(1)**

**(Total for question = 4 marks)**

Q6.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about alkenes.

Which of these has the molecular formula $C_6H_{10}$?

**(1)**

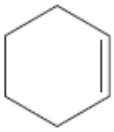
☒ **A**



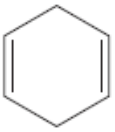
☒ **B**



☒ **C**



☒ **D**



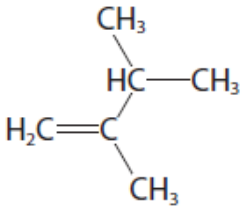
**(Total for question = 1 mark)**

Q7.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about alkenes.

What is the systematic name of this alkene?



**(1)**

☒ **A** 2-methylpent-1-ene

☒ **B** 3-methylpent-1-ene

☒ **C** 2,3-dimethylbut-1-ene

☒ **D** 2,3-dimethylbut-3-ene

**(Total for question = 1 mark)**

Q8.

**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

This question is about alkenes with the molecular formula $C_5H_{10}$.

Which of these compounds would form pent-2-ene **only**, when reacted with concentrated phosphoric acid, $H_3PO_4$?

**(1)**

☒ **A** $CH_3CH(OH)CH(CH_3)_2$

☒ **B** $CH_2(OH)CH_2CH_2CH_2CH_3$

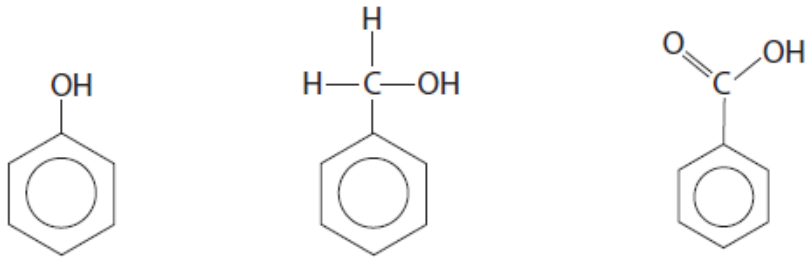
☒ **C** $CH_3CH_2CH_2CH(OH)CH_3$

☒ **D** $CH_3CH_2CH(OH)CH_2CH_3$

**(Total for question = 1 mark)**

Q9.

This is a question about the analysis of three aromatic substances with —OH groups.




phenol phenylmethanol benzoic acid

When burned in air, these aromatic compounds undergo **incomplete** combustion.

(i) Calculate the percentage composition by mass of carbon in both phenylmethanol and benzoic acid.

**(3)**

(ii) Give the expected observation when these aromatic compounds undergo incomplete combustion.

**(1)**

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(iii) Identify another **type** of organic compound which will also produce the same observation as in (ii).

**(1)**

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(iv) These combustion experiments must be carried out in a fume cupboard.




Explain why the front window of the fume cupboard must be below the safety line even with the exhaust fan switched on.

**(2)**

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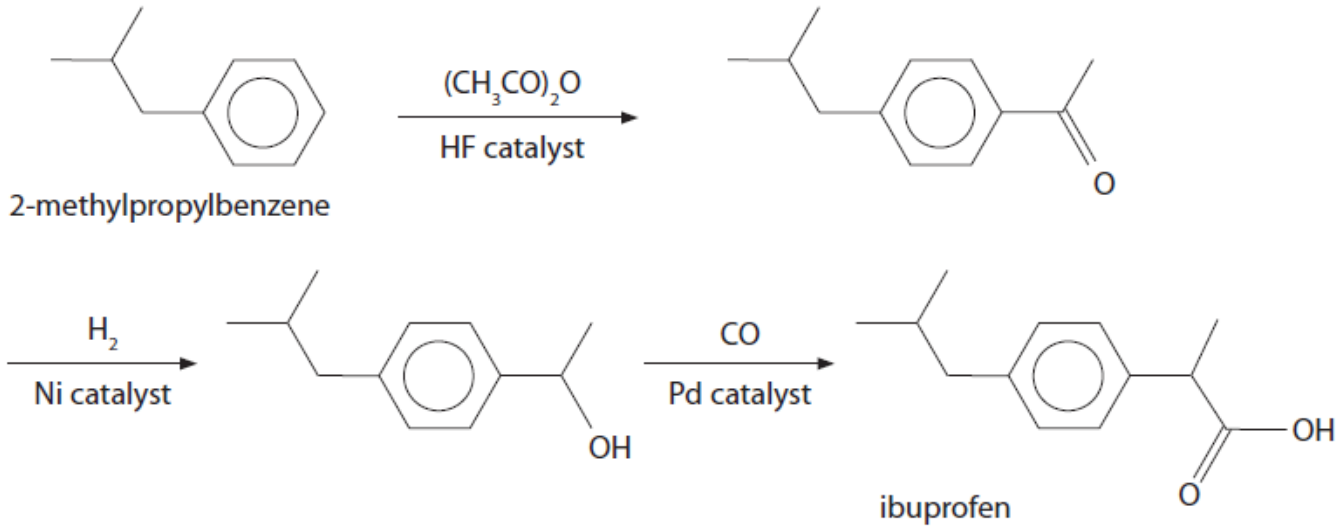
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**(Total for question = 7 marks)**

Q10.

Ibuprofen is a nonsteroidal anti-inflammatory drug (NSAID) widely used as an analgesic (pain reliever). It was discovered in the 1960s by the Boots Group which developed a six step synthesis from 2-methylpropylbenzene. The synthesis shown below was introduced in the 1990s by the BHC Company and received a Presidential Green Chemistry Challenge award in 1997. The citation noted that the synthesis has just three steps, all of which are catalytic, and an effective atom economy of 99%. Both syntheses are carried out in solution.




(a) (i) Suggest why a three step synthesis is likely to be 'greener' than a six step process.

**(1)**

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(ii) Why does the use of catalysts make processes 'greener' (as well as faster)?

**(1)**

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(b) The first step of the synthesis is an electrophilic substitution which is usually carried out in a school laboratory using ethanoyl chloride and an aluminium chloride catalyst.

(i) Write an equation showing the formation of the electrophile in the **school** experiment.

**(1)**

(ii) Give the mechanism for the electrophilic substitution of 2-methylpropylbenzene by ethanoyl chloride, using the electrophile you have given in (b)(i).

**(3)**

(iii) Suggest **one** environmental benefit of using $(CH_3CO)_2O$, rather than ethanoyl chloride, in the manufacture of ibuprofen.

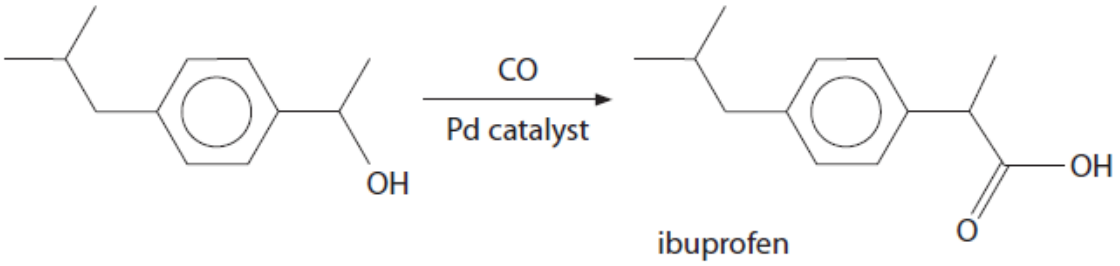
**(1)**

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(c) The final stage of the modern synthesis for ibuprofen is shown below.




ibuprofen

(i) Suggest a benefit of using a **solid** catalyst in this reaction.

**(1)**

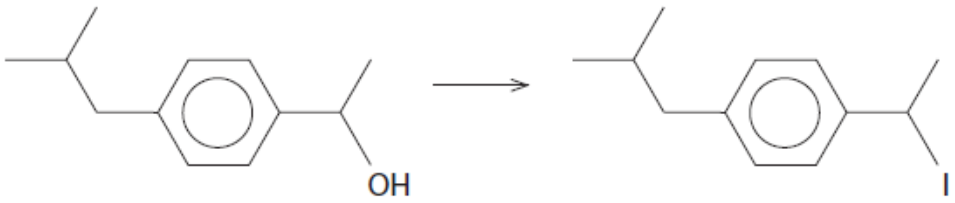
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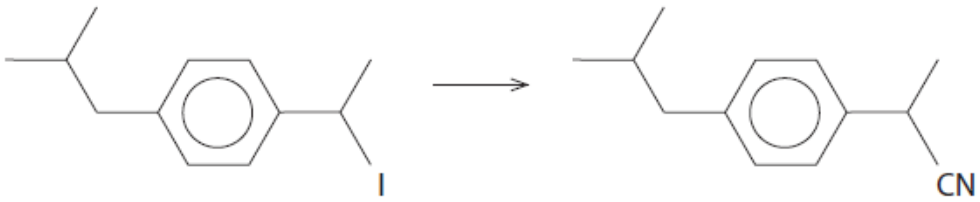
(ii) The preparation in part (c) can be carried out in a laboratory in three reactions.

**(3)**

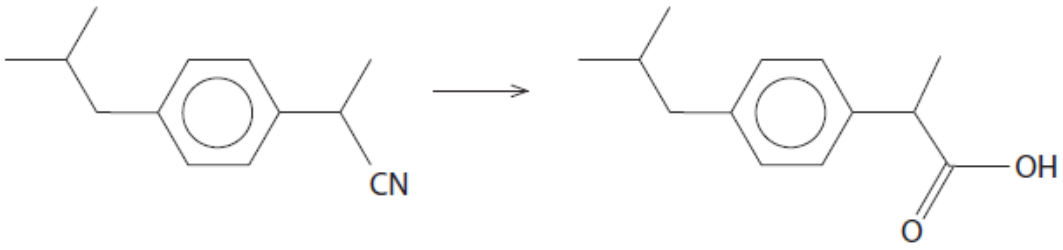
**Reaction 1**




**Reaction 2**




**Reaction 3**




Give:

The reagents for **Reaction 1**

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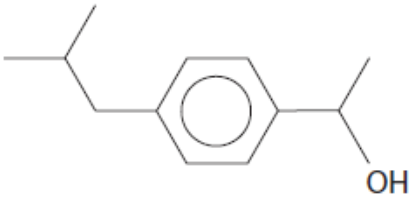
The reagents and conditions for **Reaction 3**

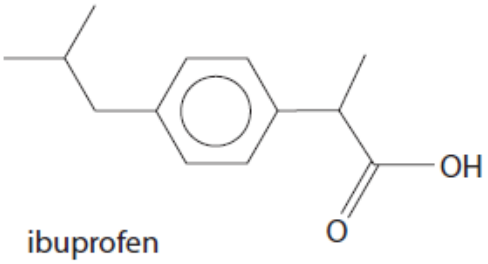
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(iii) Using your Data Booklet, explain how infrared spectroscopy can be used to distinguish between the two structures shown below.

**(2)**




ibuprofen

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(d) Ibuprofen is a chiral molecule and only one of its enantiomers is biologically active. However, although the synthesis produces a racemic mixture, an isomerase enzyme in the body converts the inactive enantiomer into the active enantiomer.

(i) Explain the term 'chiral molecule'.

**(1)**

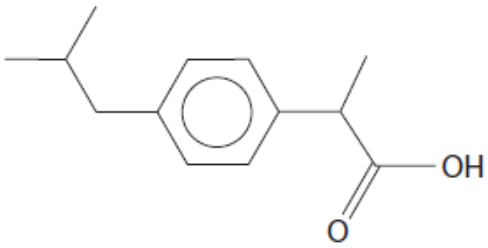
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(ii) Mark with an asterisk (*) the chiral centre on the structure of ibuprofen below.

**(1)**




(iii) Explain the term 'racemic mixture'.

**(1)**

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**(Total for question = 16 marks)**

Q11.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

Balance the ionic half-equation for the reduction of the dichromate(VI) ion.

Give the colours of all of the species involved, or state colourless if appropriate.

**(2)**

$$Cr_2O_7^{2-} + \text{.....}H^+ + \text{.....}e^- \rightarrow \text{.....}Cr^{3+} + \text{.....}H_2O$$

Colour ..... ..... ..... .....

**(Total for question = 2 marks)**

Q12.

This is a question about polymerisation.

PLA is a biodegradable polyester which is made from 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$.

(i) Draw the two enantiomers of 2-hydroxypropanoic acid.

**(2)**

(ii) State how separate samples of these two enantiomers could be distinguished in a laboratory.

**(1)**

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(iii) Biodegradable polyesters break down naturally.

State why this is an advantage.

**(1)**

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**(Total for question = 4 marks)**

Q13.

This question is about alkanes.

The black smoke produced from the incomplete combustion of alkane fuels is

**(1)**

☒ **A** carbon particulates

☒ **B** oxides of nitrogen

☒ **C** oxides of sulfur

☒ **D** unburnt hydrocarbons

**(Total for question = 1 mark)**

Q14.

Describe how the orbitals from carbon atoms interact to form the bonds in a benzene ring. You may include a labelled diagram to support your answer.

**(3)**

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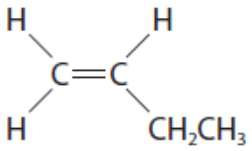
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Q15.

This question is about alkenes.

But-1-ene has the structure




(i) Draw the structure of the polymer formed when but-1-ene polymerises.

Include **two** repeat units.

**(1)**

(ii) Calculate the number of molecules in 70.0 g of but-1-ene.

[Avogadro constant = $6.02 \times 10^{23}$ $mol^{-1}$]

**(2)**

**(Total for question = 3 marks)**

Q16.

This question is about the chemistry of iodine compounds and hydrocarbons.

Iodine monochloride (ICl) reacts with unsaturated compounds such as sunflower oil.

Sunflower oil can be hydrogenated to form solid fats such as margarine.
What is the **most** appropriate catalyst for this reaction?

**(1)**

☒ **A** nickel

☒ **B** iron

☒ **C** rhodium

☒ **D** vanadium(V) oxide

Q17.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.

| | | |
|---|---|---|
| $CH_3CH_2CH_2COOH$ | or | $HOCH_2CH{=}CHCH_2OH$ |
| **A** | | **B** |

Deduce a **chemical** test which would give a positive result for **B** but **not** for **A**.
Include the reagent and observation.

**(2)**

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**(Total for question = 2 marks)**

Q18.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.

| | | |
|---|---|---|
| $CH_3CH_2CH_2COOH$ | or | $HOCH_2CH{=}CHCH_2OH$ |
| **A** | | **B** |

Deduce a **chemical** test which would give a positive result for **A** but **not** for **B**.
Include the reagent and observation.

**(2)**

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**(Total for question = 2 marks)**

Q19.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about hydrocarbons.

When hydrocarbons undergo complete combustion, there is a change in the total volume of gases.

(i) Ethane burns in excess oxygen.

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

All gas volumes are measured at the same temperature and pressure when water is a gas.

What is the **increase** in the total volume when 100 $cm^3$ of ethane is burned in excess oxygen?

**(1)**

☒ **A** 50 $cm^3$

☒ **B** 100 $cm^3$

☒ **C** 200 $cm^3$

☒ **D** 500 $cm^3$

(ii) A combustion experiment was carried out using conditions under which water was a liquid.

A cyclic hydrocarbon, $C_xH_y$, was mixed with excess oxygen and ignited.
Under the conditions of the experiment, this hydrocarbon was gaseous and had a volume of 25 $cm^3$.

The equation for the complete combustion of $C_xH_y$ is

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

The total gas volume **decreased** by 75 $cm^3$.
The remaining gases were shaken with aqueous sodium hydroxide and the total gas volume **decreased** by a further 125 $cm^3$.

All gas volumes were measured at the same temperature and pressure.

Suggest the identity of the cyclic hydrocarbon by calculating the molecular formula of $C_xH_y$.
Include the **skeletal formula** of the cyclic hydrocarbon.

**(3)**

**(Total for question = 4 marks)**

Q20.

Both polystyrene and paper can be used to manufacture cups. Some people argue that using polystyrene for cups is more sustainable than using paper.

Evaluate the data in the table and hence justify which material you think is more sustainable.

**(6)**

| | Paper cup | Polystyrene cup |
|---|---|---|
| **Raw materials (per cup)** | | |
| Wood or bark | 26 g | 0 g |
| Petroleum fractions | 2.2 g | 3.4 g |
| **Energy used (per tonne of material made)** | 980 kwh | 280 kwh |
| **Water released into environment (per tonne of material made)** | 120 $m^3$ | 2.5 $m^3$ |
| **Air emissions (per tonne of material made)** | | |
| Chlorine / chlorine dioxide | 0.4 kg | 0 kg |
| Sulfides / sulfur dioxide | 11 kg | 3.5 kg |
| Hydrocarbons | 0 kg | 40 kg |

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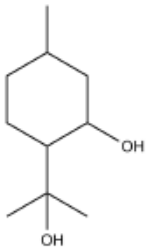
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Q21.

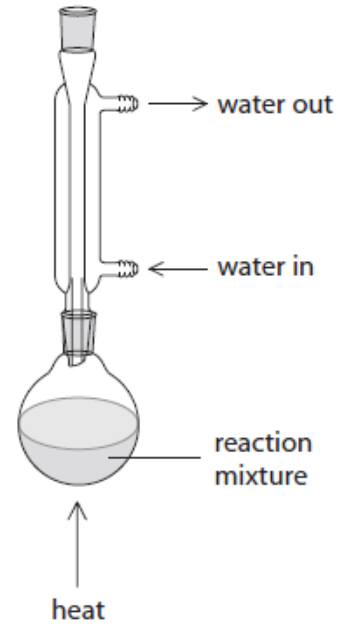
Alcohols contain the hydroxyl functional group. They can be oxidised using appropriate reagents and conditions.

Alcohol **Y** contains two hydroxyl groups.

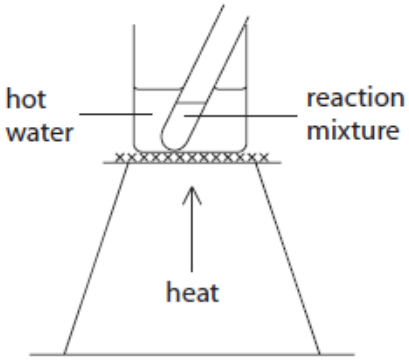



Alcohol **Y** can be oxidised by heating it with sodium dichromate(VI) solution and sulfuric acid.

*(a)  A student suggested two possible techniques for heating the reaction mixture.




Technique A




Technique B

Evaluate all aspects of the two techniques and justify which one is more appropriate to just show that alcohol **Y** is able to be oxidised.

**(6)**

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(b) Explain, using information from the Data Booklet, whether hydrochloric acid is a suitable alternative to sulfuric acid in the reaction mixture.

**(2)**

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(c) Draw the **skeletal** formula of the organic product formed by the oxidation of alcohol **Y**.

**(1)**

**(Total for question = 9 marks)**

Q22.

This is a question about the hydrolysis of halogenoalkanes.

Devise an experiment, giving outline details only, that would enable the relative rates of hydrolysis of halogenoalkanes to be compared.

**(5)**

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**(Total for question = 5 marks)**

Q23.

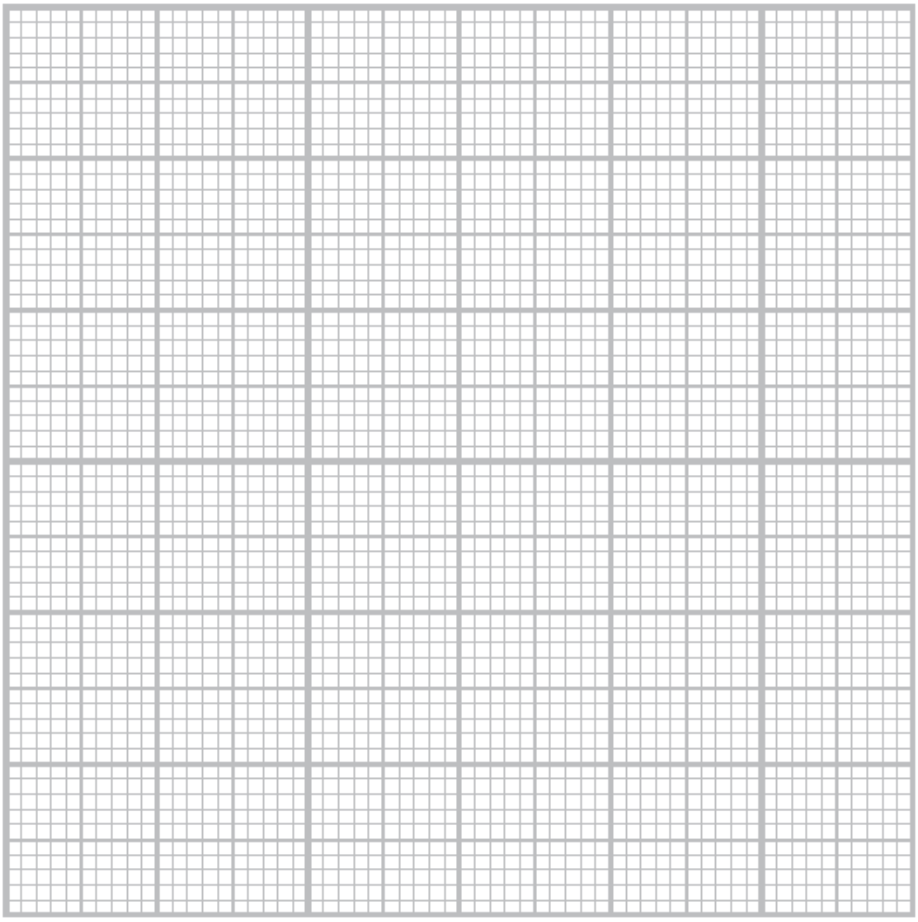
A series of experiments was carried out to determine the kinetics of the reaction between a chloroalkane, RCl, and potassium hydroxide in aqueous solution.
A large excess of the chloroalkane was used.

The data obtained are shown.

| $[OH^-]$ / mol $dm^{-3}$ | Time / s |
|---|---|
| 0.00100 | 39 |
| 0.00200 | 31 |
| 0.00300 | 23 |
| 0.00400 | 16 |
| 0.00500 | 8 |

(a) Plot a graph of the concentration of the hydroxide ions against time.

**(2)**



(b) State the order with respect to hydroxide ions.
Justify your answer by reference to your graph in (a).

**(2)**

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(c) Deduce the type of mechanism occurring.
Justify your answer.

**(2)**

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(d) Give the classification of the chloroalkane in this reaction.

**(1)**

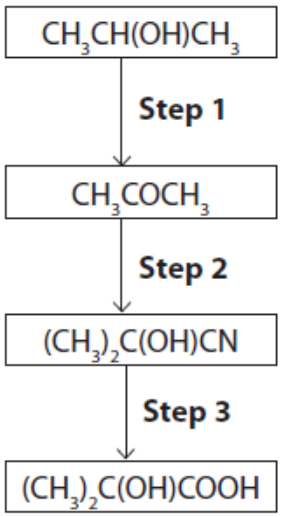
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**(Total for question = 7 marks)**

Q24.

A flow chart for making 2-hydroxy-2-methylpropanoic acid from propan-2-ol is shown below.




(a) (i) Give the reagents and conditions for **Step 1**.

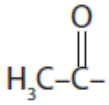
**(2)**

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(ii) Propanone is formed in Step 1.

Give a chemical test to identify the carbonyl group and a further test to show the presence of the  group.

For both tests, give the observations that you would make.

**(4)**

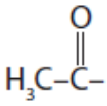
Carbonyl group

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 group

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(b) (i) In **Step 2**, propanone undergoes an addition reaction with HCN in the presence of $CN^-$ ions.
Give the mechanism for this reaction.

**(3)**

(ii) Explain why this reaction would not take place at either a very low or very high pH.

**(2)**

Low pH

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High pH

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(c) (i) The reaction in **Step 3** forms 2-hydroxy-2-methylpropanoic acid, $(CH_3)_2C(OH)COOH$.
Suggest the type of reaction occurring in **Step 3**.

**(1)**

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(ii) Explain why the presence of the alcoholic hydroxyl group cannot be confirmed in the infrared spectrum of 2-hydroxy-2-methylpropanoic acid.

**(1)**

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(iii) The hydrogen of the alcohol group in 2-hydroxy-2-methylpropanoic acid can be identified by a single peak in the nmr spectrum.

Give the chemical shift you would expect for this peak.

**(1)**

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(iv) How many peaks would you expect in a high resolution nmr spectrum for 2-hydroxy-2-methylpropanoic acid, $(CH_3)_2C(OH)COOH$?

**(1)**

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(v) Explain why, in high resolution nmr, the peak due to the hydrogens of the 2-methyl group in 2-hydroxy-2-methylpropanoic acid is a singlet.

**(1)**

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(vi) Would you expect 2-hydroxy-2-methylpropanoic acid to have optical isomers? Justify your answer.

**(1)**

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(d) (i) Molecules of 2-hydroxy-2-methylpropanoic acid react together to form a condensation polymer.

Draw a **displayed** formula for this polymer, showing two repeating units.

**(2)**

(ii) Give the name of the functional group that links the two molecules in the polymer.

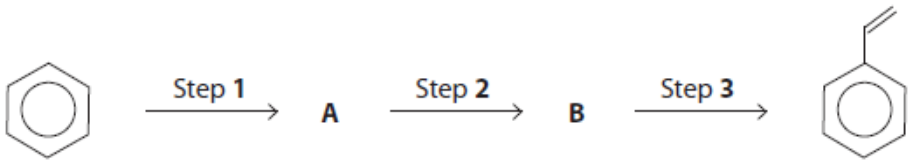
**(1)**

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**(Total for question = 20 marks)**

Q25.

Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.




Give one advantage and one disadvantage of the disposal of polystyrene by incineration.

**(2)**

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**(Total for question = 2 marks)**

Q26.

This is a question about polymerisation.

But-1-ene and cyclohexene both form addition polymers.

Draw a section of each polymer, showing **two** repeat units.

**(2)**

$CH_2{=}CHCH_2CH_3$ →

 →

**(Total for question = 2 marks)**

Q27.

The chemistry of organic compounds containing a chlorine atom is affected by the presence of other groups.

Consider the reaction of ammonia, $NH_3$, with $CH_3CH_2CH_2Cl$ and with $CH_3CH_2COCl$.

Draw the mechanism for the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia to form the primary amine. Include curly arrows and relevant lone pairs.

**(3)**

**(Total for question = 3 marks)**

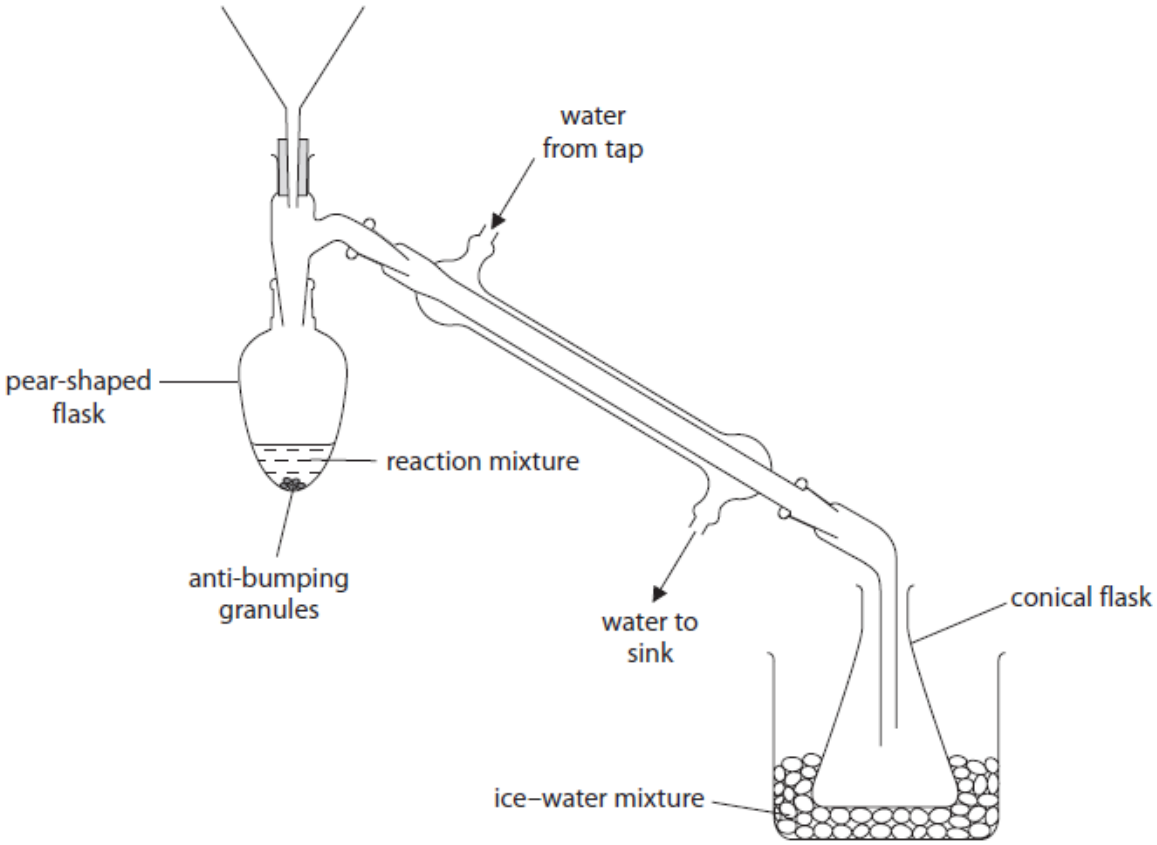
Q28.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.




Draw the **skeletal** formulae for 3-methylbutan-2-ol and 3-methylbutan-2-one.

**(2)**

3-methylbutan-2-ol

3-methylbutan-2-one

**(Total for question = 2 marks)**

Q29.

This is a question about halogenoalkanes and related compounds.

The halogenoalkane 2-bromobutane reacts with ethanolic potassium hydroxide to produce a mixture of alkenes.

Draw the **skeletal** formulae of all the alkenes that could be produced.

**(3)**

**(Total for question = 3 marks)**

Q30.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

Reflux apparatus can be used to carry out the oxidation of alcohols.

Using the apparatus for distillation instead of reflux is not an efficient way to produce ethanoic acid from ethanol. Explain why.

**(2)**

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**(Total for question = 2 marks)**

Q31.

This question is about carboxylic acids and their derivatives.

(a) Which method can be used to produce a carboxylic acid using only the reactants shown?

**(1)**

☒ **A** hydrolysis of ethyl ethanoate with sodium hydroxide solution

☒ **B** hydrolysis of butanenitrile with dilute hydrochloric acid

☒ **C** reaction of butanoyl chloride with concentrated ammonia

☒ **D** reaction of but-2-ene with acidified potassium manganate(VII)

(b) Which of these reagents can be used to make the ester, propyl ethanoate, in a single step

reaction?

**(1)**

☒ **A** $CH_3CH_2CHO$ and $CH_3CH_2OH$

☒ **B** $CH_3CH_2COCl$ and $CH_3CH_2OH$

☒ **C** $CH_3CHO$ and $CH_3CH_2CH_2OH$

☒ **D** $CH_3COCl$ and $CH_3CH_2CH_2OH$

(c) Gas chromatography is used in conjunction with mass spectrometry to analyse esters found in drinks.

State the purpose of each technique.

(i) Gas chromatography

**(1)**

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(ii) Mass spectrometry

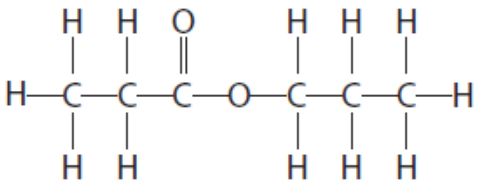
**(1)**

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Q32.

This question is about esters with the molecular formula $C_6H_{12}O_2$.

Propyl propanoate has the structure shown.



Devise a synthetic pathway to prepare propyl propanoate starting with 1-bromopropane as the **only** organic compound.

Include the reagents for each step in the synthesis, and the names or structures of the intermediate compounds.

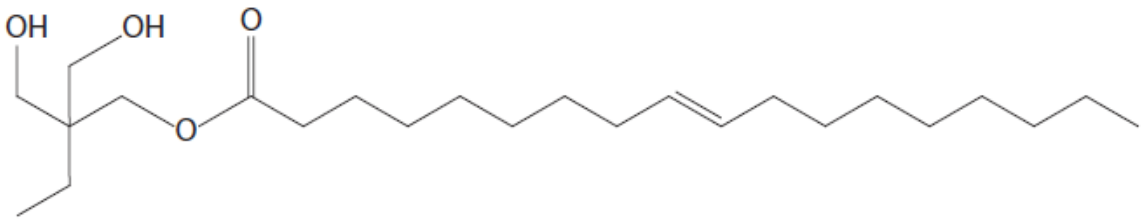
**(5)**

**(Total for question = 5 marks)**

Q33.

**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.




compound **X**

An alternative to synthetic oil is known as mineral oil and consists solely of hydrocarbons separated from crude oil.

(i) What is the name of the process used to separate different hydrocarbons from crude oil?

**(1)**

☒ **A** cracking

☒ **B** reforming

☒ **C** fractional distillation

☒ **D** heating under reflux

(ii) Explain why compound **X** is likely to have a higher boiling temperature than hydrocarbons of a similar molecular mass and shape.

A detailed description of how the intermolecular forces arise is not required.

**(2)**

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**(Total for question = 3 marks)**

Q34.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Gentian violet is a purple crystalline solid used as an antifungal treatment.

It can be synthesised from dimethylphenylamine, $C_6H_5N(CH_3)_2$ .

The dimethylphenylamine used in the synthesis can be made by the stepwise reaction of phenylamine with chloromethane.

Step **1** $2C_6H_5NH_2 + CH_3Cl \rightarrow C_6H_5NH(CH_3) + C_6H_5NH_3^+Cl^-$

Step **2** $2C_6H_5NH(CH_3) + CH_3Cl \rightarrow C_6H_5N(CH_3)_2 + C_6H_5NH_2^+(CH_3)Cl^-$

The reaction mechanism for Step **1** between phenylamine and chloromethane is the same as that in the reaction between ammonia and chloromethane.

(i) What is the reaction type and mechanism in Step **1**?

**(1)**

☐ **A** electrophilic addition

☐ **B** electrophilic substitution

☐ **C** nucleophilic addition

☐ **D** nucleophilic substitution

(ii) Draw the mechanism for the reaction in Step **1**.

Include curly arrows, and relevant lone pairs and dipoles.

**(4)**

(iii) Describe, in outline, how a sample of a solid, such as gentian violet, is purified by recrystallisation.

Specific details of the solvent used are not required.

**(4)**

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**(Total for question = 9 marks)**

Q35.

This question is about compounds of Group 5 elements.

Which of these compounds produces hydrogen chloride when it reacts with $PCl_5$?

**(1)**

☒ **A** propanal

☒ **B** propan-1-ol

☒ **C** propanone

☒ **D** propyl propanoate

**(Total for question = 1 mark)**

Q36.

The table shows the formulae of three different halogenoalkanes and the optical activity of the products of their reaction with hydroxide ions in aqueous solution.

| Reaction | Halogenoalkane reacting with hydroxide ions | Optical activity of product mixture |
|---|---|---|
| 1 | $CH_3Cl$ | none |
| 2 | $CH_3CHBrCH_2CH_3$ | significant |
| 3 | $CH_3CH_2CH_2C(Br)(CH_3)CH_2CH_3$ | no significant activity |

(a) Draw the mechanism for reaction **1**.

**(4)**

(b) The halogenoalkane in reaction **2** is 2-bromobutane.

(i) Name the halogenoalkane in reaction **3**.

**(1)**

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*(ii) Both halogenoalkanes used in reaction **2** and reaction **3** were a single optical isomer.

Explain the optical activity of the product mixture for reaction **2** and reaction **3**, in terms of the reaction mechanism.

**(6)**

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Q37.

Cinnamon is a spice that is extracted from the bark of the cinnamon tree.

It is extracted by crushing the soft bark with water, and then steam distilling the mixture to produce cinnamon oil.

(b) Compound **Q** is the main component of cinnamon oil. Some chemical tests are carried out to try to find the structure of **Q**.

The results of each test are given in parts (i) to (iii).

Deduce from the results of each test what functional group may be present in **Q**.

(i) **Q** decolourises both bromine water and acidified potassium manganate(VII).

**(1)**

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(ii) **Q** gives a yellow precipitate with 2,4-dinitrophenylhydrazine.

**(1)**

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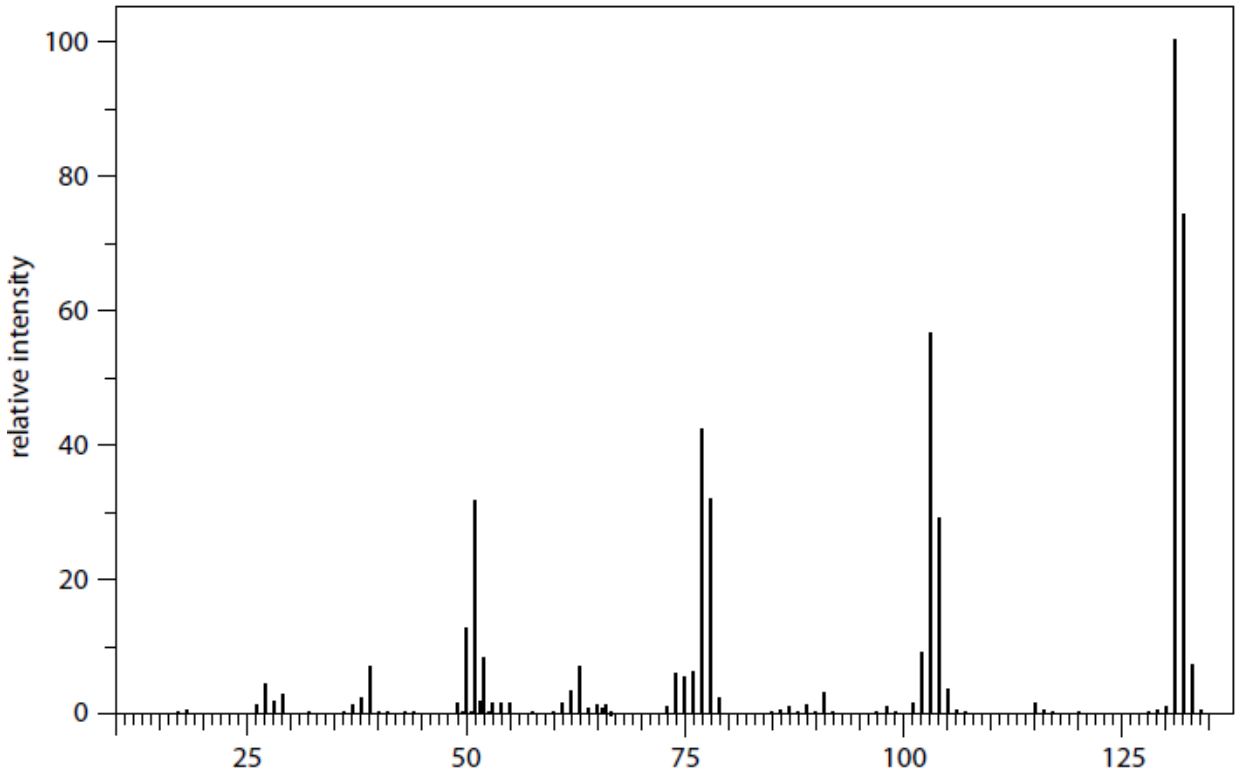
(iii) **Q** forms a red precipitate when boiled with either Benedict's or Fehling's solution.

**(1)**

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(c) **Q** has the empirical formula $C_9H_8O$ and its mass spectrum is shown.




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(i) Predict the identity of the fragment ions causing the peaks at 77 and 103.

**(2)**

| m/z | formula of fragment ion |
|---|---|
| 77 | |
| 103 | |

(ii) Deduce **two** possible displayed formulae for **Q**.

**(2)**

(iii) The peak at m/z = 132 in the mass spectrum of **Q** is the molecular ion peak. The mass spectrum also shows a peak at m/z = 133.

Give a reason why the peak at m/z = 133 occurs.

**(1)**

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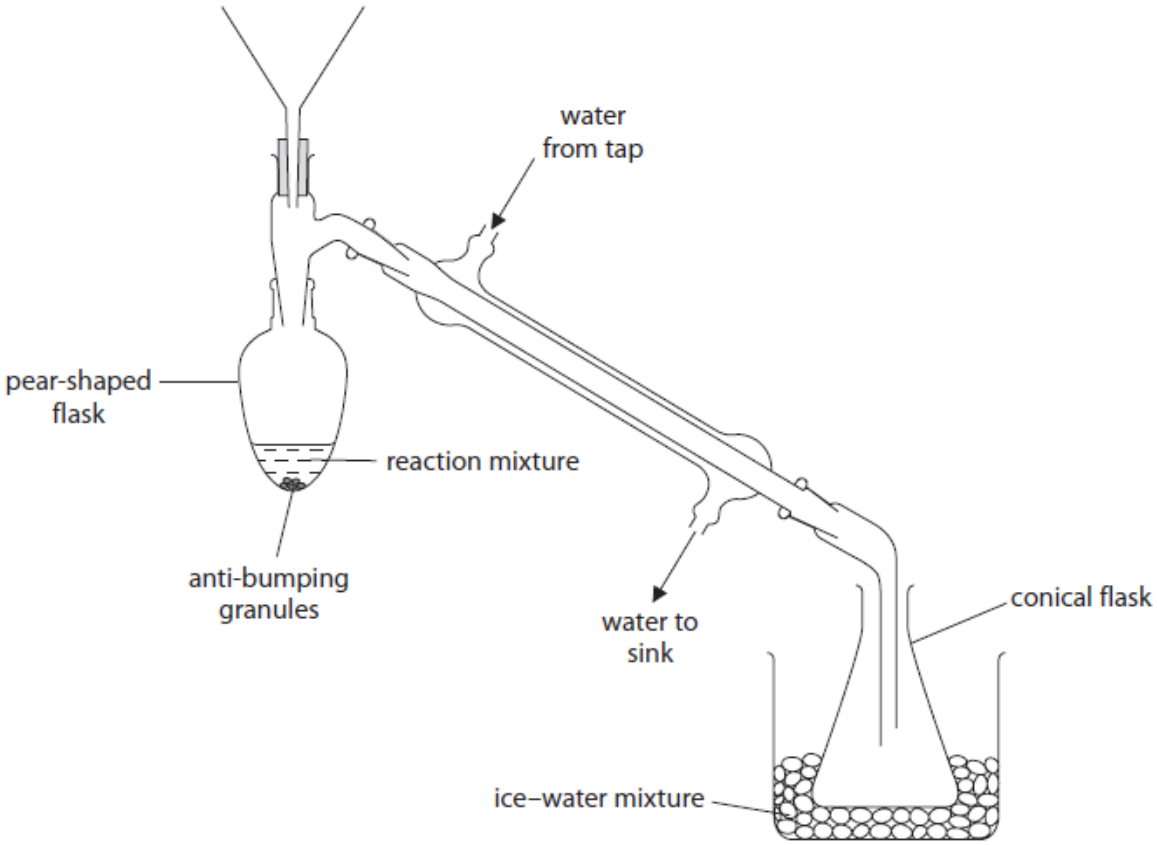
Q38.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.




Identify the **two** changes that must be made to the apparatus before heating the pear-shaped flask, giving a reason for each change.

**(4)**

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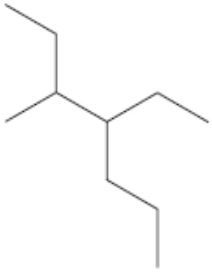
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**(Total for question = 4 marks)**

Q39.

This is a question about alkanes.

What is the name of this alkane?



**(1)**

- ☒ **A** 2-ethyl-3-propylpentane
- ☒ **B** 4-ethyl-3-methylheptane
- ☒ **C** 3-methyl-4-propylhexane
- ☒ **D** 4-methyl-3-propylhexane

**(Total for question = 1 mark)**

Q40.

This is a question about alkanes.

What is the reaction mechanism when ethane and chlorine react in UV light?

**(1)**

- ☒ **A** electrophilic addition
- ☒ **B** electrophilic substitution
- ☒ **C** free radical addition
- ☒ **D** free radical substitution

**(Total for question = 1 mark)**

Q41.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about hydrocarbons.

Which of these molecular formulae represents a non-cyclic, saturated hydrocarbon?

**(1)**

☒ **A** $C_6H_6$

☒ **B** $C_6H_{10}$

☒ **C** $C_6H_{12}$

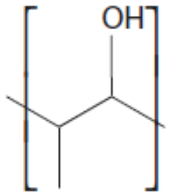
☒ **D** $C_6H_{14}$

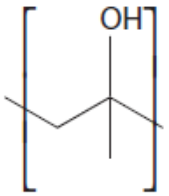
**(Total for question = 1 mark)**

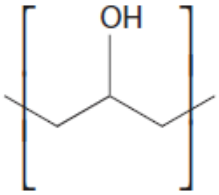
Q42.

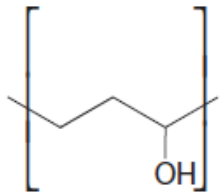
The monomer of the addition polymer poly(propenol) may be represented as $CH_3{-}CH{=}CHOH$.

The repeat unit of the addition polymer is

☒ **A** 


☒ **B** 


☒ **C** 

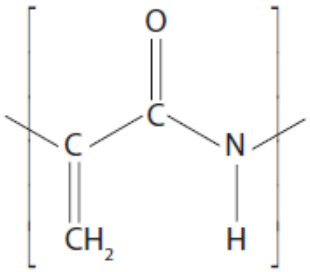

☒ **D** 


**(Total for question = 1 mark)**

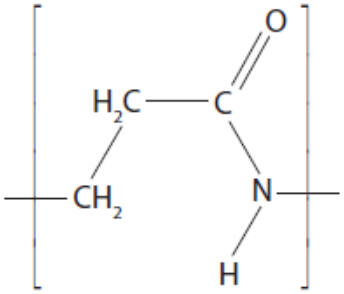
Q43.

The monomer of the addition polymer poly(propenamide) is is $CH_2{=}CHCONH_2$. The repeat unit of the polymer is

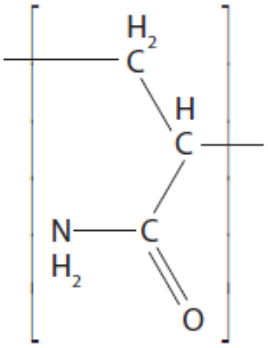
☒ **A**



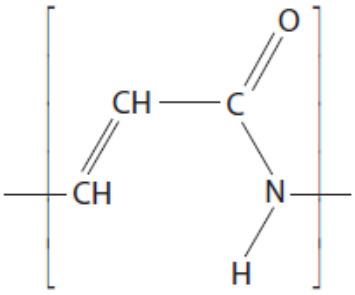

☒ **B**




☒ **C**




☒ **D**



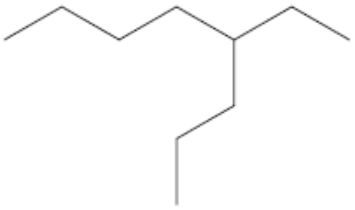

**(Total for question = 1 mark)**

Q44.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about alkanes and their reactions.

What is the IUPAC name for this alkane?



**(1)**

☒ **A** 4-ethyloctane

☒ **B** 5-ethyloctane

☒ **C** 3-propylheptane

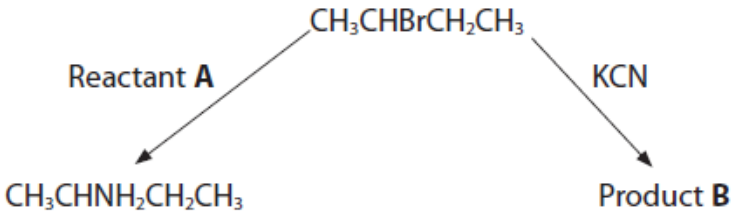
☒ **D** 5-propylheptane

**(Total for question = 1 mark)**

Q45.

This question is about halogenoalkanes.

(a) Some reactions of 2-bromobutane are:




(i) Give the **formula** for Reactant **A**.

**(1)**

.....

(ii) Give the **displayed** formula of the organic Product **B**.

**(1)**

(b) Which of these statements best explains why 2-chlorobutane reacts with potassium cyanide at a slower rate than 2-bromobutane?

**(1)**

☒

**A** the C-Cl bond has a higher bond enthalpy than the C-Br bond

☒ **B** the C-Cl bond has a lower bond enthalpy than the C-Br bond

☒ **C** the C-Cl bond is less polar than the C-Br bond

☒ **D** the C-Cl bond is more polar than the C-Br bond

(c) Halogenoalkanes are hydrolysed by hydroxide ions to form alcohols.

(i) Give reasons why these reactions are classified as nucleophilic substitution.

**(2)**

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(ii) Which of the following shows the relative rate of hydrolysis of 1-bromobutane, 2-bromobutane and 2-bromo-2-methylpropane?

**(1)**

| | | Fastest rate ⟶ | | Slowest rate |
|---|---|---|---|---|
| ☒ | **A** | 1-bromobutane | 2-bromobutane | 2-bromo-2-methylpropane |
| ☒ | **B** | 1-bromobutane | 2-bromo-2-methylpropane | 2-bromobutane |
| ☒ | **C** | 2-bromo-2-methylpropane | 1-bromobutane | 2-bromobutane |
| ☒ | **D** | 2-bromo-2-methylpropane | 2-bromobutane | 1-bromobutane |

(iii) The reaction between 2-bromo-2-methylpropane and hydroxide ions takes place in two steps.

$$(CH_3)_3CBr \rightarrow (CH_3)_3C^+ + Br^- \qquad \text{slow}$$

$$(CH_3)_3C+ + OH^- \rightarrow (CH_3)_3COH \qquad \text{fast}$$

Give the rate equation for the reaction of 2-bromo-2-methylpropane with hydroxide ions. Justify your answer.

**(2)**

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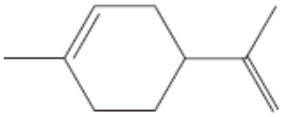
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**(Total for question = 8 marks)**

Q46.

This question is about hydrocarbons.

Limonene is obtained from the oil in lemon peel and it is the only alkene present.



0.500 g of the oil reacted with exactly 30.6 $cm^3$ of a solution of bromine dissolved in cyclohexane with a concentration of 0.200 mol $dm^{-3}$.

Calculate the percentage by mass of limonene in the oil.
Give your answer to an appropriate number of significant figures.

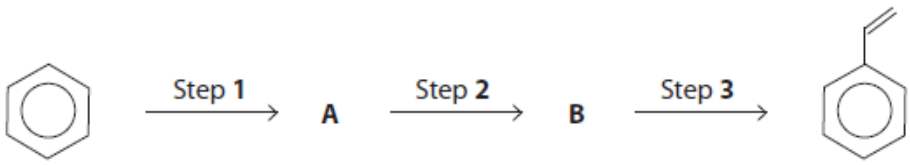
Assume that there is nothing else in the oil that reacts with bromine.

**(4)**

**(Total for question = 4 marks)**

Q47.

Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.




Some of the following compounds can be used to make phenylethene from benzene.

| | | | |
|---|---|---|---|
| Aluminium chloride | Chloroethane | Ethanal | Ethanol |
| Ethanoic acid | Ethanoyl chloride | Ethene | Ether |
| Hydrochloric acid, concentrated | Lithium tetrahydridoaluminate(III) | Phosphoric acid, concentrated | Sulfuric acid, concentrated |

Selecting **only** from these compounds, devise a synthetic pathway for converting benzene into phenylethene, clearly identifying compounds **A** and **B** and stating the appropriate conditions for each step.

**(5)**

**(Total for question = 5 marks)**

Q48.

The first step in the reaction between chlorine and propane involves the formation of chlorine radicals.

(i) What type of bond breaking produces radicals?

**(1)**

☒ **A** heterolytic fission

☒ **B** heterolytic fusion

☒ **C** homolytic fission

☒ **D** homolytic fusion

(ii) Write equations for the propagating steps in the mechanism to form 2-chloropropane.

**(2)**

(iii) Explain why it is difficult to produce a pure sample of 2-chloropropane when chlorine reacts with propane.

**(2)**

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Q49.

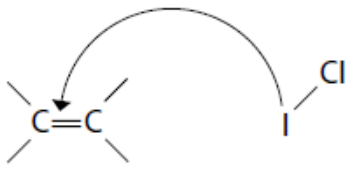
This question is about the chemistry of iodine compounds and hydrocarbons.

Iodine monochloride (ICl) reacts with unsaturated compounds such as sunflower oil.

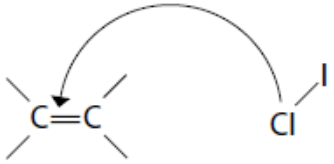
(i) Which diagram shows the first step in the mechanism of the reaction between iodine monochloride and an unsaturated compound?

**(1)**

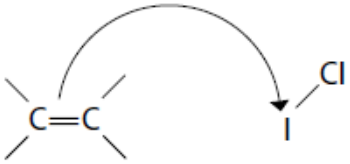
☒ **A**



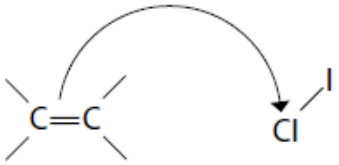

☒ **B**




☒ **C**




☒ **D**




(ii) What is the name and type of the mechanism in the overall reaction?

**(1)**

☒ **A** electrophilic substitution

☒ **B** nucleophilic substitution

☒ **C** electrophilic addition

☒ **D** nucleophilic addition

Q50.

This is a question about the hydrolysis of halogenoalkanes.

* Compare and contrast the mechanism of hydrolysis, using aqueous potassium hydroxide, of the primary halogenoalkane, $RCH_2X$, with that of the tertiary halogenoalkane, $R_3CX$.
Include diagrams of any intermediate or transition state.

Curly arrows are not required.

**(6)**

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**(Total for question = 6 marks)**

Q51.

**Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.

Methyl cinnamate undergoes an addition reaction in the dark with bromine.

(i) Draw the mechanism for the reaction between methyl cinnamate and bromine, $Br_2$.

Include curly arrows, and relevant lone pairs and dipoles.

**(4)**

(ii) Deduce the number of optical isomers of the addition product that can exist.

**(1)**

☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 8

(iii) When plane-polarised light is passed through an optical isomer, the plane of polarisation is

**(1)**

☒ **A** diffracted

☒ **B** reflected

☒ **C** refracted

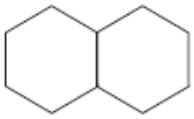
☒ **D** rotated

**(Total for question = 6 marks)**

Q52.

This question is about alkanes.

The skeletal formula of decalin is



The molecular formula of decalin is

**(1)**

☒ **A** $C_{10}H_{22}$

☒ **B** $C_{10}H_{20}$

☒ **C** $C_{10}H_{18}$

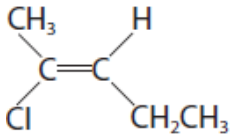
☒ **D** $C_{10}H_{16}$

**(Total for question = 1 mark)**

Q53.

Q1.

Name the compound below.




☒ **A** *E*-2-chloropent-2-ene

☒ **B** *Z*-2-chloropent-3-ene

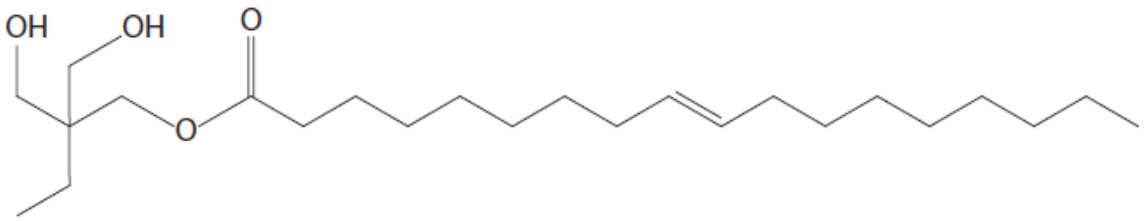
☒ **C** *E*-2-chloropent-3-ene

☒ **D** *Z*-2-chloropent-2-ene

**(Total for question = 1 mark)**

Q2.

Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.




compound **X**

Name the **three** functional groups present in compound **X**.

**(2)**

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**(Total for question = 2 marks)**

Q3.

This question is about some hydrocarbons.

(i) Which isomeric alkane has the lowest boiling temperature?

**(1)**

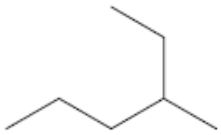
☒ **A** 2,2-dimethylbutane

☒ **B** hexane

☒ **C** 3-methylpentane

☒ **D** 2-methylpentane

(ii) What is the name of this alkane?



**(1)**

☒ **A** 4-ethylpentane

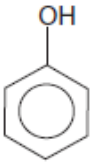
☒ **B** 2-ethylpentane

☒ **C** 4-methylhexane

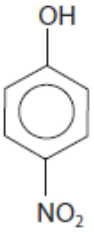
☒ **D** 3-methylhexane

Q4.

Phenol is a feedstock in the production of many organic molecules.

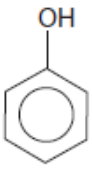



Phenol can be nitrated to produce 4-nitrophenol.



(i) The mechanisms of the nitration of phenol and of benzene are similar. Complete the diagram, using curly arrows, to show a possible mechanism for the reaction between the electrophile, $NO_2^+$, and phenol to produce 4-nitrophenol.

**(3)**







(ii) What is the mass, in grams, of 4-nitrophenol produced from 0.94 g of phenol if the yield of this isomer is 15%?

**(1)**

☒ **A** 0.14

☒ **B** 0.21

☒ **C** 0.68

☒ **D** 1.39

(iii) Draw **two** structural isomers of 4-nitrophenol which have a benzene ring.

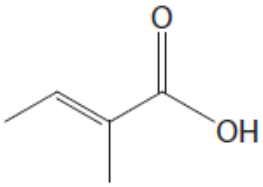
**(1)**

**(Total for question = 5 marks)**

Q5.

**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

What is the systematic name for tiglic acid?




tiglic acid

☒ **A** *E*-2-methylbut-2-enoic acid

☒ **B** *Z*-2-methylbut-2-enoic acid

☒ **C** *E*-3-methylbut-2-enoic acid

☒ **D** *Z*-3-methylbut-2-enoic acid

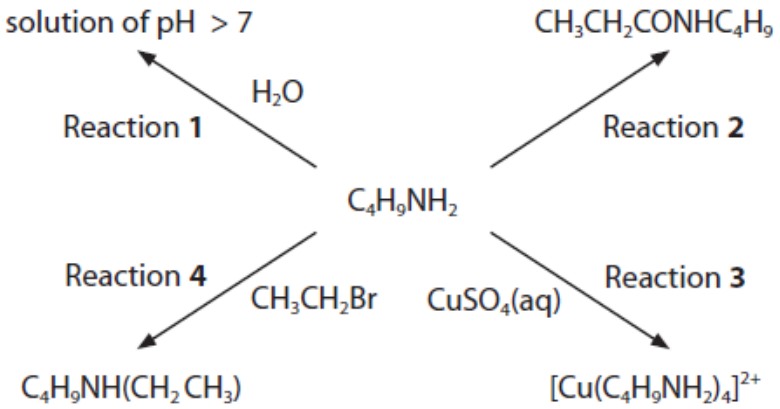
**(Total for question = 1 mark)**

Q6.

**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

This question is about the amines butylamine, $C_4H_9NH_2$, and phenylamine, $C_6H_5NH_2$.

The reaction scheme shows some reactions of butylamine, a primary amine.




(i) What is the type and mechanism of the reaction in Reaction **4**?

**(1)**

☒ **A** electrophilic addition

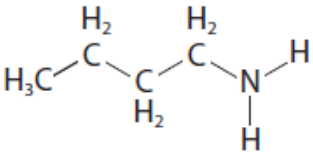
☒ **B** electrophilic substitution

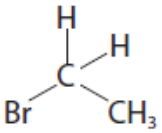
☒ **C** nucleophilic addition

☒ **D** nucleophilic substitution

(ii) Complete the diagram to show the mechanism for Reaction **4**.
Include curly arrows, and relevant lone pairs and dipoles.

**(4)**





**(Total for question = 5 marks)**

Q7.

A bromoalkane, RBr, reacts with aqueous hydroxide ions in a nucleophilic substitution reaction.

$$RBr + OH^- \rightarrow R—OH + Br^-$$

This reaction is first order with respect to the bromoalkane and the rate equation is

$$\text{rate} = k[RBr]^1[OH^-]^x$$

where x is the order of the reaction with respect to hydroxide ions.

In an experiment, a sample of the bromoalkane was added to a large excess of aqueous sodium hydroxide and the concentration of the bromoalkane was determined at regular time intervals.

**Results**

| Time / s | [RBr] / mol dm$^{-3}$ |
|---|---|
| 0 | 0.100 |
| 30 | 0.065 |
| 60 | 0.042 |
| 90 | 0.028 |
| 120 | 0.019 |
| 150 | 0.014 |

This experiment is carried out using the bromoalkane dissolved in ethanol and the hydroxide ions dissolved in water.

Give a reason why a solution of hydroxide ions dissolved in pure ethanol should **not** be used.

**(1)**

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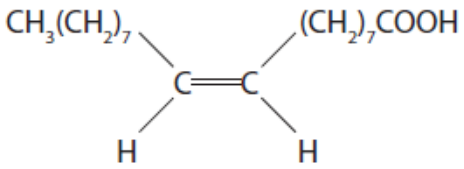
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**(Total for question = 1 mark)**

Q8.

The formula for oleic acid, which is present in fingerprints, is shown below.




(a) The systematic name for oleic acid is

**(1)**

☒ **A** *E*-octadec-9-enoic acid.

☒ **B** *Z*-octadec-9-enoic acid.

☒ **C** *E*-octadec-8-enoic acid.

☒ **D** *Z*-octadec-8-enoic acid.

(b) Which intermolecular forces are present between oleic acid molecules?

**(1)**

☒ **A** Hydrogen bonds only.

☒ **B** Hydrogen bonds and permanent dipole-dipole forces only.

☒ **C** Hydrogen bonds, permanent dipole-dipole forces and London forces.

☒ **D** Hydrogen bonds and London forces only.

(c) Which of the following species is most likely to cause a peak at *m/e* = 45 in the mass spectrum of oleic acid?

**(1)**

☒ **A** $CH_2CH_2OH$

☒ **B** $CH_2CH_2OH^+$

☒ **C** COOH

☒ **D** $COOH^+$

(d) What would you expect to see if oleic acid is tested separately with bromine water and with phosphorus(V) chloride, $PCl_5$?

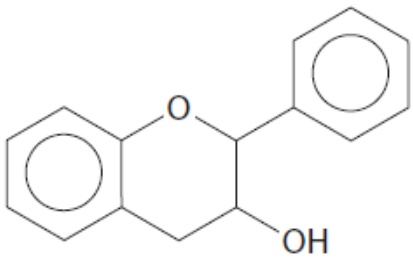
**(1)**

| | Bromine water | Phosphorus(V) chloride, $PCl_5$ |
|---|---|---|
| ☐ **A** | Decolorises | Steamy fumes |
| ☐ **B** | No colour change | No visible change |
| ☐ **C** | Decolorises | No visible change |
| ☐ **D** | No colour change | Steamy fumes |

**(Total for question = 4 marks)**

Q9.

The compound flavan-3-ol is found in tea, fruit and wine.




*A sample of flavan-3-ol extracted from wine contained some ethanol. The sample was left in a flask, open to the air for several days. The contents were then analysed to identify any new compounds formed. Several new compounds were found to be present, including some with a distinctive fruity smell.

Identify **four** new organic compounds that could form under these conditions by considering the chemistry of alcohols. Justify your answers. Include the structure of two compounds formed from flavan-3-ol, one of which has a fruity smell.

**(6)**

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**(Total for question = 6 marks)**

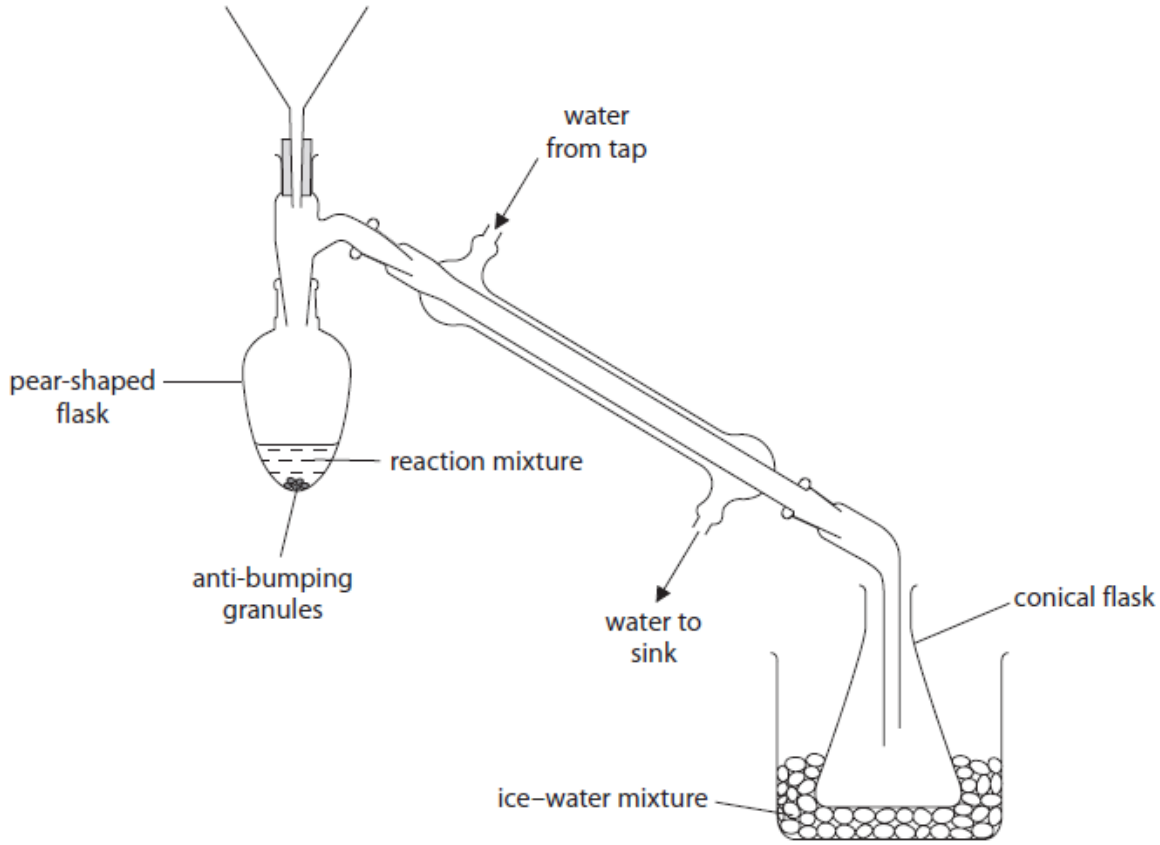
Q10.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.




The sample of purified 3-methylbutan-2-one is found to have a mass of 2.15 g.
This mass of 3-methylbutan-2-one represents a yield of 62.5% by mass.

(i) Write an equation, using **molecular** formulae, for the oxidation of 3-methylbutan-2-ol to 3-methylbutan-2-one.

Use [O] to represent the oxidising agent.

**(2)**

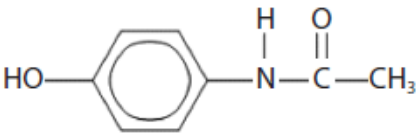
(ii) Calculate the mass of 3-methylbutan-2-ol that the student uses at the start of the preparation.

**(2)**

**(Total for question = 4 marks)**

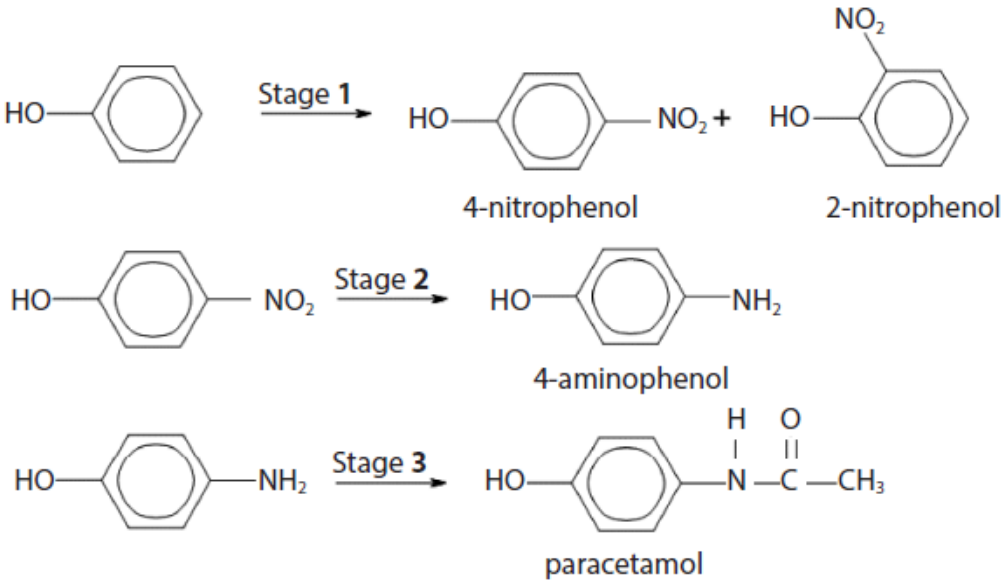
Q11.

This question is about the preparation and analysis of paracetamol.



paracetamol

Paracetamol may be prepared from phenol in three stages.

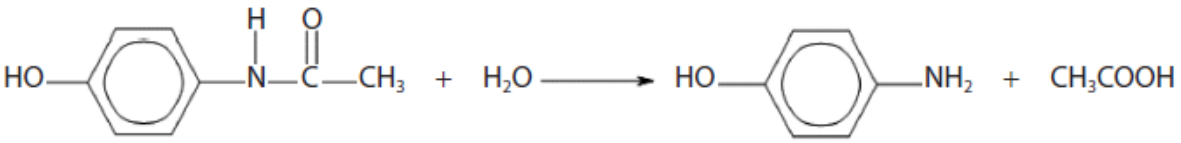



The percentage by mass of paracetamol in three brands of paracetamol tablets are shown in the table.

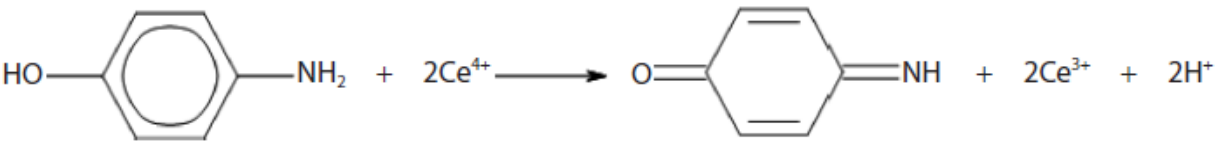
| Brand of tablet | Percentage by mass of paracetamol |
|---|---|
| P | 92.1 |
| Q | 93.6 |
| R | 99.7 |

The amount of paracetamol in a tablet can be determined using a titration with cerium(IV) ions.

The tablets are crushed and then hydrolysed in acid to form 4-aminophenol.



4-aminophenol is oxidised by cerium(IV) ions.



A tablet from one of the three brands of paracetamol was analysed following the outline procedure.

- one of the tablets was crushed and 0.500 g of the powder was added to dilute sulfuric acid
- the mixture was heated under reflux until the hydrolysis was complete

- the solution was made up to 100.0 $cm^3$ in a volumetric flask
- 25.0 $cm^3$ portions of the solution were titrated against 0.100 mol $dm^{-3}$ $Ce^{4+}$ using ferroin as indicator

**Result**

The mean titre was 16.50 $cm^3$.

(i) Give the molecular formula of paracetamol.

**(1)**

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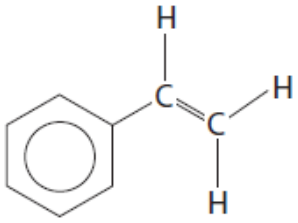
(ii) Determine, by calculation, which brand of tablet was analysed.

**(5)**

**(Total for question = 6 marks)**

Q12.

The compound phenylethene (styrene) is used in the manufacture of polymers.




A simple test for the alkene functional group, such as that in styrene, is the addition of a small amount of bromine dissolved in cyclohexane.

(i) State the colour change you would expect to see in this test.

**(1)**

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(ii) Explain what happens to the bromine molecule as it gets close to the alkene functional group.

**(2)**

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(iii) Give the type of reaction that occurs and draw the structure of the product formed in the test for the alkene functional group.

**(2)**

Type of reaction

.....

Structure

(iv) Draw the repeat unit of the polymer formed from phenylethene.

**(1)**

Q13.

**Benzene**

Benzene was first discovered by Michael Faraday in London in 1825. He identified it by distilling a liquid obtained from condensing a gas produced by heating whale oil.

In 1834, Mitscherlich discovered the same liquid could be obtained by heating benzoic acid with lime.

Benzene is now produced from petroleum. Petroleum is fractionally distilled and benzene is obtained from the hexane in the naphtha fraction.

Hexane is heated to about 770 K. It then passes to a reactor where it reacts to form cyclohexane and hydrogen. The cyclohexane is then dehydrogenated to form benzene. Other aromatic products like methylbenzene and dimethylbenzenes are also produced. The aromatic products are separated by further distillation.

Benzene is the starting compound for a large number of useful chemicals and materials. For example it is used to make the polymer, poly(phenylethene).

Phenylethene is used to make the polymer poly(phenylethene).

Write an equation for the polymerization of phenylethene.

**(2)**

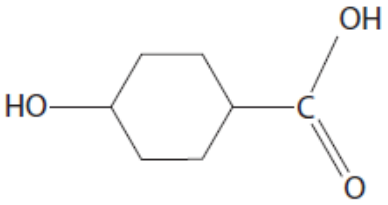
Q14.

* This question is about polymers.

Compare and contrast how each of these monomers forms a polymer.



cyclohexene




4-hydroxycyclohexanecarboxylic acid

Include equations, showing the formation of a single repeat unit for each polymer.

**(6)**

**(Total for question = 6 marks)**

Q15.

This question is about polymers.

Give three ways in which waste polymers can be utilised to improve their sustainability.

**(3)**

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**(Total for question = 3 marks)**

Q16.

1-bromobutane can be prepared from butan-1-ol and hydrogen bromide.

$$CH_3CH_2CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

Hydrogen bromide can be made from sodium bromide and 50% concentrated sulfuric acid.

(a) The steps for the preparation of impure 1-bromobutane are summarised.

Step **1** Dissolve the sodium bromide in distilled water in a pear-shaped flask and then add 20.0 $cm^3$ of butan-1-ol.

Step **2** Surround the flask with an ice bath to **cool the mixture**, before adding concentrated sulfuric acid drop by drop.

Step **3** Remove the flask from the ice bath and add a few **anti-bumping granules** to the reaction mixture.

Step **4** Set up the apparatus for **heating under reflux**. Heat the mixture in the flask for 30 minutes and then allow the apparatus to cool.

Step **5** Rearrange the apparatus for distillation and heat the mixture until no more 1-bromobutane distils over.

(i) Parts of the method are given in **bold** type in Steps **2**, **3** and **4**.

Give a reason why each of these parts is necessary.

**(3)**

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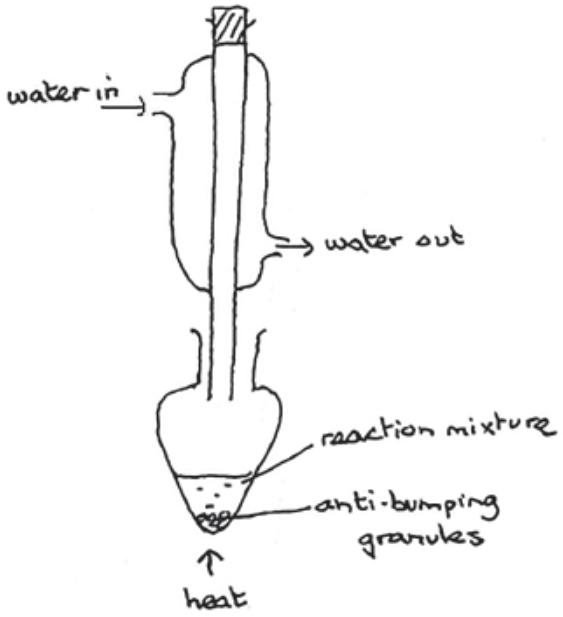
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(ii) A student drew a diagram of the apparatus used for heating under reflux in Step **4**. There are three errors in the apparatus shown in the diagram.
Assume the apparatus is suitably clamped.




Identify the three errors, including the effect of each error.

**(3)**

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(iii) The student corrected the errors.

While the mixture was heating under reflux, the student noticed a small amount of a brown vapour was formed.

Explain why the brown vapour forms.

**(2)**

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(b) The distillate collected in Step **5** is a mixture consisting of two layers.

There is an aqueous layer and a layer containing impure 1-bromobutane.

**Data**

Densities:

| | |
|---|---|
| water | $1.00\,g\,cm^{-3}$ |
| butan-1-ol | $0.81\,g\,cm^{-3}$ |
| 1-bromobutane | $1.27\,g\,cm^{-3}$ |

Boiling temperature of 1-bromobutane = 102 °C

The steps for the purification of the 1-bromobutane are summarised.

Step **6** Transfer the mixture from Step **5** to a separating funnel and remove the aqueous layer.

Step **7** Wash the impure 1-bromobutane with concentrated hydrochloric acid in the separating funnel.

Remove the aqueous layer.

Step **8** Add aqueous sodium hydrogencarbonate to the impure 1-bromobutane in the separating funnel.

Step **9** Shake the mixture in the separating funnel and, from time to time, invert the funnel and open the tap.

Step **10** Collect the 1-bromobutane layer from Step **9** in a small conical flask.

Add anhydrous sodium sulfate and swirl the flask until the liquid becomes clear.

Step **11** Decant the 1-bromobutane into a clean pear-shaped flask and redistil it. Measure the volume of 1-bromobutane produced.

(i) State the position of the aqueous layer in the separating funnel at the start of Step **6**. Justify your answer.

**(1)**

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(ii) Concentrated hydrochloric acid is used to remove any unreacted butan-1-ol in the mixture in Step **7**.

Give the reasons for carrying out Steps **8**, **9** and **10**.

**(3)**

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.....

(iii) Give a suitable temperature **range** over which to collect the pure 1-bromobutane in the redistillation in Step **11**.

**(1)**

.....

(iv) The volume of 1-bromobutane collected was 12.0 $cm^3$.

Calculate the number of molecules of 1-bromobutane produced in this experiment.

Give your answer to an appropriate number of significant figures.

**(2)**

**(Total for question = 15 marks)**

Q17.

**Answer the question with a cross in the box you think is correct ☒. If you change your**

**mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about some reactions of alcohols.

Which reagent is used with iodine to prepare iodoalkanes from alcohols?

**(1)**

☒ **A** red phosphorus

☒ **B** concentrated phosphoric acid

☒ **C** sulfur

☒ **D** concentrated sulfuric acid

**(Total for question = 1 mark)**

Q18.

This question is about alkanes and their reactions.

What is the name of the process that could be used to produce propane, $C_3H_8$, from decane, $C_{10}H_{22}$?

**(1)**

☒ **A** substitution

☒ **B** reforming

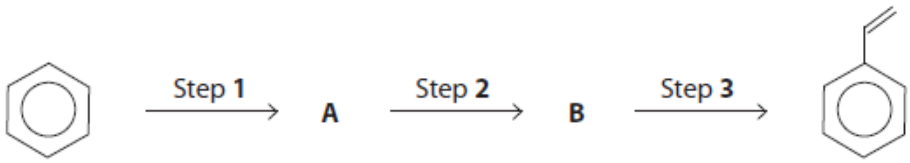
☒ **C** fractional distillation

☒ **D** cracking

**(Total for question = 1 mark)**

Q19.

Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.




Which reagent could produce a diol from phenylethene?

**(1)**

☒ **A** acidified potassium dichromate(VI)

☒ **B** acidified potassium manganate(VII)

☒ **C** aqueous sodium hydroxide

☒ **D** steam

**(Total for question = 1 mark)**

Q20.

This question is about four organic compounds, each containing two carbon atoms.

**A** $CH_3CH_2OH$

**B** $CH_3CHO$

**C** $CH_3COOH$

**D** $CH_3COCl$

(a) Which is oxidized by ammoniacal silver nitrate?

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which has the highest boiling temperature?

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) 0.01 mol of each compound is heated separately with excess acidified sodium dichromate(VI).

Which compound reduces the largest amount of sodium dichromate(VI)?

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) 0.01 mol of each compound is added separately to identical volumes of water. Which solution would have the lowest pH?

**(1)**

☒ **A**

☒ **B**

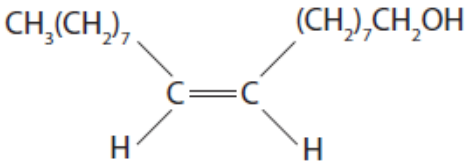
☒ **C**

☒ **D**

**(Total for question = 4 marks)**

Q21.

The formula for oleyl alcohol, which is present in sperm whale oil and was used as a lubricant, is shown below.




(a) The systematic name for oleyl alcohol is

**(1)**

☒ **A** *E*-octadec-9-en-1-ol.

☒ **B** *Z*-octadec-9-en-1-ol.

☒ **C** *E*-octadec-8-en-1-ol.

☒ **D** *Z*-octadec-8-en-1-ol.

(b) Which intermolecular forces are present between oleyl alcohol molecules?

**(1)**

☒ **A** London forces only

☒ **B** Hydrogen bonds and London forces only

☒ **C** Hydrogen bonds and permanent dipole–dipole forces only

☒ **D** Hydrogen bonds, permanent dipole–dipole and London forces

(c) Which of the following is the most likely structure of the species to cause a peak at *m/e* 31 in the mass spectrum of oleyl alcohol?

**(1)**

☒ **A** $CH_3O$

☒ **B** $CH_2OH$

☒ **C** $CH_3O^+$

☒ **D** $CH_2OH^+$

(d) What would you expect to see if oleyl alcohol is tested separately with bromine water and heated with acidified sodium dichromate(VI) solution?

**(1)**

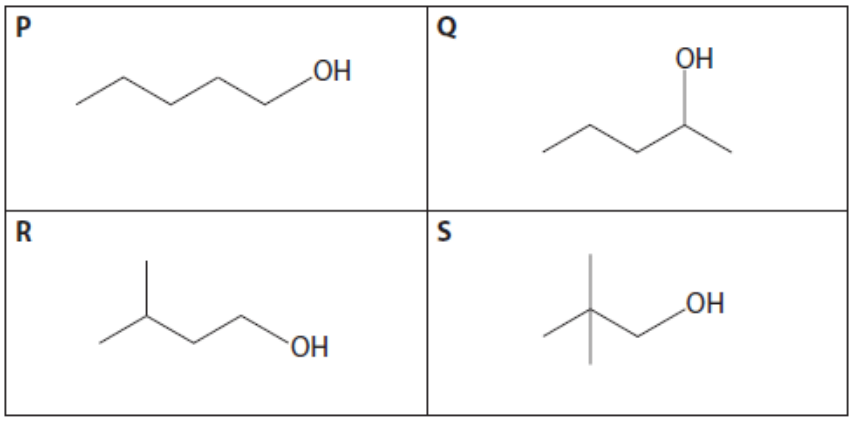
| | Bromine water | Acidified sodium dichromate(VI) solution |
|---|---|---|
| ☒ **A** | Decolorises | Turns green |
| ☒ **B** | No colour change | No colour change |
| ☒ **C** | Decolorises | No colour change |
| ☒ **D** | No colour change | Turns green |

**(Total for question = 4 marks)**

Q22.

This question is about alcohols.

The skeletal formulae of four alcohols with molecular formula $C_5H_{12}O$ are shown.




(i) Which of the alcohols has a chiral centre?

**(1)**

☒ **A** alcohol **P**

☒ **B** alcohol **Q**

☒ **C** alcohol **R**

☒ **D** alcohol **S**

(ii) Which of the alcohols are classified as primary?

**(1)**

☒ **A** alcohol **P** only

☒ **B** alcohols **P** and **R** only

☒ **C** alcohols **P**, **R** and **S** only

☒ **D** alcohols **P**, **Q**, **R** and **S**

(iii) Which of the alcohols can be oxidised to form 3-methylbutanoic acid?

**(1)**

☒ **A** alcohol **P**

☒ **B** alcohol **Q**

☒ **C** alcohol **R**

☒ **D** alcohol **S**

Q23.

Four organic compounds are:

**A** $CH_3OH$

**B** HCHO

**C** HCOOH

**D** $HCOOCH_3$

(a) Which of these compounds has a fruity smell?

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) 0.01 mol of each compound is added separately to identical volumes of water.
Which solution would have the lowest pH?

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) 0.01 mol of each compound is heated separately with excess acidified sodium dichromate(VI) solution. Which compound reduces the largest amount of sodium dichromate(VI)?

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) Which compound has the highest boiling temperature?

**(1)**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(e) Which of these compounds can be oxidized by ammoniacal silver nitrate?

**(1)**

☒ **A**

☒ **B**

☒ **C**

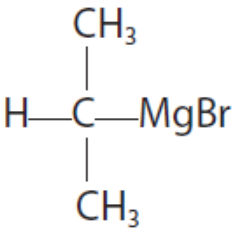
☒ **D**

**(Total for question = 5 marks)**

Q24.

Grignard reagents are used in organic synthesis as a way of increasing the length of the carbon chain in a molecule.

(a) The structure of the Grignard reagent formed by the reaction between 2-bromopropane and magnesium is



On the diagram, draw the permanent dipole involving the central carbon atom.

**(1)**

(b) The Grignard reagent in part (a) reacts with propanal.

(i) Draw the **fully displayed** formula of the final organic product of this reaction.

**(1)**

(ii) Name the organic product in (b)(i).

**(1)**

.....

(c) Identify, by using ticks, **two** boxes in the table to select appropriate terms that describe a Grignard reagent.

**(2)**

| | |
|---|---|
| acid | |
| electrophile | |
| nucleophile | |
| oxidising agent | |
| reducing agent | |

(d) The solvent used for Grignard reagents has to be completely **dry**.

By considering the dipole on the O—H bonds in water, predict the identity of the organic product that forms if water is added to the Grignard compound in part (a).

**(1)**

.....

**(Total for question = 6 marks)**

Q25.

When one optically active isomer of 3-chloro-3-methylhexane reacts with hydroxide ions to form 3-methylhexan-3-ol, a racemic mixture forms because

☒ **A** 3-chloro-3-methylhexane forms a carbocation intermediate.

☒ **B** the reaction is a nucleophilic substitution.

☒ **C** 3-chloro-3-methylhexane forms a five-bonded transition state.

☒ **D** 3-methylhexan-3-ol contains a chiral carbon.

**(Total for question = 1 mark)**

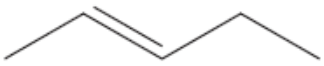
Q26.

This question is about alkenes with the molecular formula $C_5H_{10}$.

Pent-2-ene reacts with hydrogen bromide, HBr, to form two bromoalkanes.

Complete the diagram to show the mechanism for the formation of 2-bromopentane in this reaction.
Include curly arrows, and relevant lone pairs and dipoles.

**(4)**






**(Total for question = 4 marks)**

Q27.

This question is about hydrocarbons.

Propene reacts with iodine monochloride, ICl, by an electrophilic addition mechanism.

Draw the mechanism for the reaction between propene and iodine monochloride to form the **major** product.

Include the dipole on the ICl molecule, curly arrows and any relevant lone pairs of electrons.

**(4)**

**(Total for question = 4 marks)**

Q28.

This question is about alkanes.

The reaction of ethane and chlorine in UV radiation produces chloroethane.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

This reaction is classified as

**(1)**

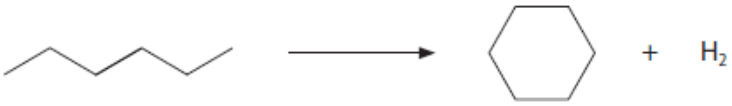
- ☒ **A** addition
- ☒ **B** elimination
- ☒ **C** initiation
- ☒ **D** substitution

**(Total for question = 1 mark)**

Q29.

This question is about alkanes.

A reaction of hexane is shown below.




This is **best** described as

**(1)**

- ☒ **A** elimination
- ☒ **B** hydrogenation
- ☒ **C** isomerisation
- ☒ **D** reforming

**(Total for question = 1 mark)**

Q30.

This is a question about catalytic converters in car exhaust systems.

When petrol is burnt in a car engine, pollutant gases including carbon monoxide and nitrogen monoxide are formed.

(i) Write the equation for the reaction between these two polluting gases that takes place on the surface of a catalytic converter. State symbols are not required.

**(1)**

(ii) Describe the stages by which the reaction in (i) occurs in a catalytic converter.

**(3)**

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**(Total for question = 4 marks)**

Q31.

**Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about some reactions of alcohols.

(i) Which alcohol **cannot** be oxidised by acidified potassium dichromate(VI)?

**(1)**

☒ **A** hexan-2-ol

☒ **B** 2-methylpentan-2-ol

☒ **C** hexan-3-ol

☒ **D** 2-methylpentan-3-ol

(ii) Which alcohol reacts with iodine in the presence of alkali to form a yellow solid?

**(1)**

☒ **A** hexan-2-ol

☒ **B** 2-methylpentan-2-ol

☒ **C** hexan-3-ol

☒ **D** 2-methylpentan-3-ol

**(Total for question = 2 marks)**

Q32.

This is a question about halogenoalkanes and related compounds.

Explain the trend in reactivity of the **primary** chloro-, bromo- and iodoalkanes with aqueous hydroxide ions.

**(2)**

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**(Total for question = 2 marks)**

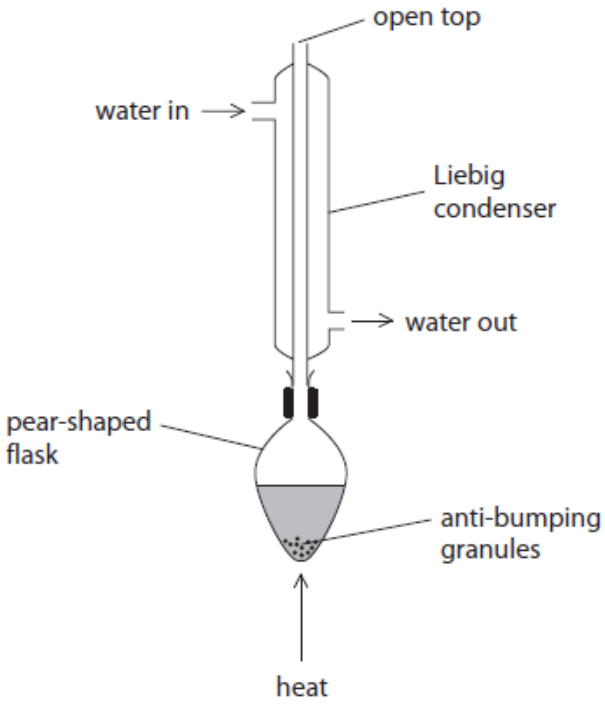
Q33.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

Reflux apparatus can be used to carry out the oxidation of alcohols.

(i) This Liebig condenser has been set up incorrectly. Add shading to the diagram to show the water in the condenser, illustrating the effect of the incorrect water flow.

**(1)**




(ii) State how the granules prevent bumping.

**(1)**

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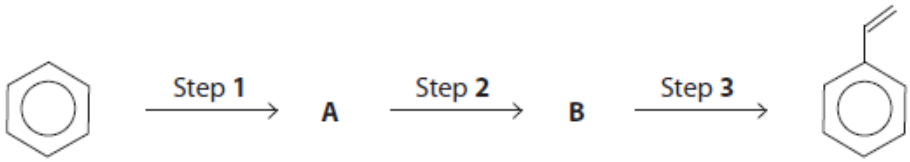
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**(Total for question = 2 marks)**

Q34.

Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.




Draw a section of the polymer, polystyrene, showing **two** repeat units.

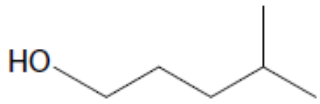
**(1)**

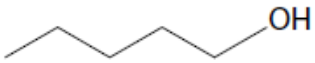


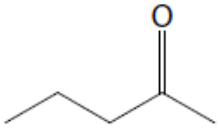
**(Total for question = 1 mark)**

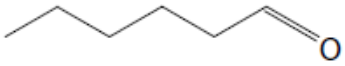
Q35.

The skeletal formulae of four compounds are shown.

**A** 


**B** 


**C** 


**D** 


Which compound has the molecular formula $C_6H_{14}O$?

**(1)**

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

Q36.

This question is about alkenes with the molecular formula $C_5H_{10}$.

Draw the **skeletal** formulae of three **branched** chain alkenes with the molecular formula $C_5H_{10}$.

**(3)**







**(Total for question = 3 marks)**

Q37.

Draw the **skeletal** formulae of the four isomers of alkenes with molecular formula $C_4H_8$.

**(3)**

Q38.

The table shows the formulae of three different halogenoalkanes and the optical activity of the products of their reaction with hydroxide ions in aqueous solution.

| Reaction | Halogenoalkane reacting with hydroxide ions | Optical activity of product mixture |
|---|---|---|
| 1 | $CH_3Cl$ | none |
| 2 | $CH_3CHBrCH_2CH_3$ | significant |
| 3 | $CH_3CH_2CH_2C(Br)(CH_3)CH_2CH_3$ | no significant activity |

Compounds containing the alkene functional group can show stereoisomerism.

(i) Draw the **two** structural isomers for an alkene that shows stereoisomerism.

**(1)**

(ii) Explain why stereoisomerism occurs in alkenes.

**(2)**

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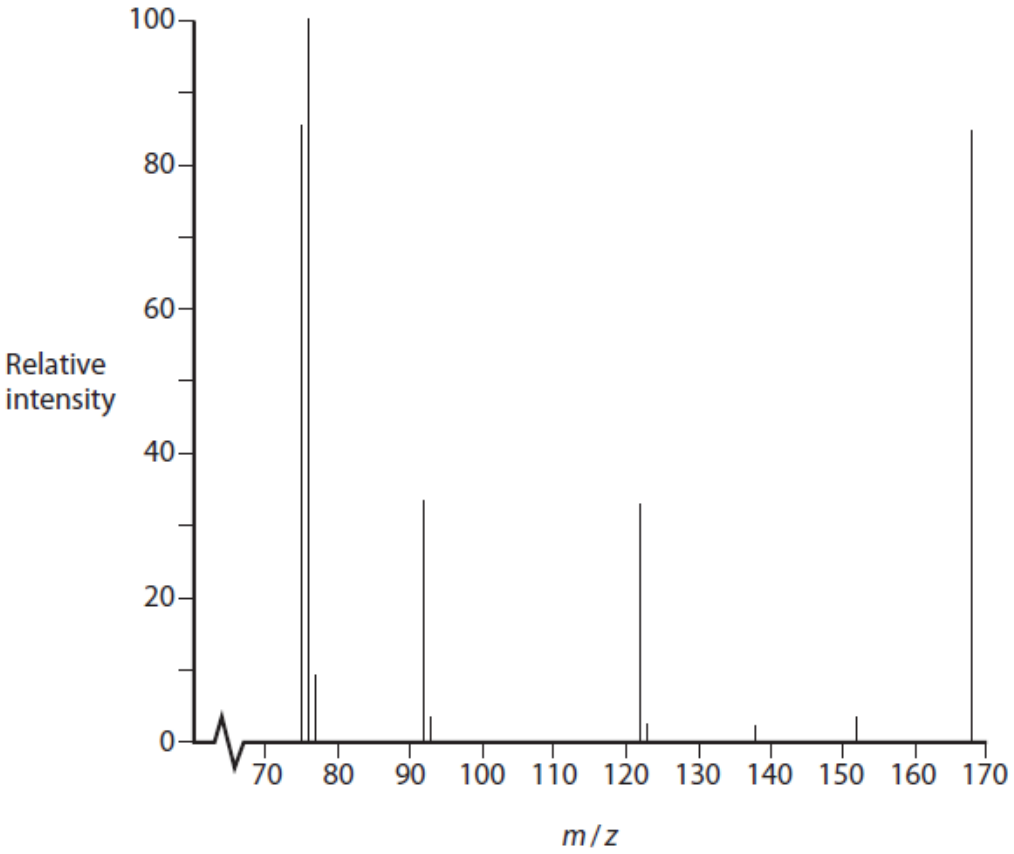
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Q39.

Organic compound **D** contains the elements carbon, hydrogen, oxygen and nitrogen only.

Part of the mass spectrum of **D** is shown.




Compound **D** contains a benzene ring.

(i) Give the molecular formula of the species that causes the peak at $m / z = 76$ in the mass spectrum of **D**.

.....

**(1)**

(ii) Draw the structures of the **three** possible isomers of **D** containing a benzene ring.

**(2)**

(iii) The $^{13}C$ NMR spectrum of compound **D** has four peaks.

Identify the structure of **D**. Justify your answer by labelling the different carbon environments in **all** the structures drawn in (ii).

**(3)**

**(Total for question = 6 marks)**

Q40.

**Answer the question with a cross in the box you think is correct ☒. If you change your**

**mind about an answer, put a line through the box . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about hydrocarbons.

How many **structural** isomers are there with the molecular formula $C_5H_{12}$?

**(1)**

☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 5

**(Total for question = 1 mark)**

Q41.

This question is about esters with the molecular formula $C_6H_{12}O_2$.

Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed.
It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of
but-1-ene and but-2-ene.

Deduce the structures of **B** and **A**. Justify your structure of **B**.

**(3)**

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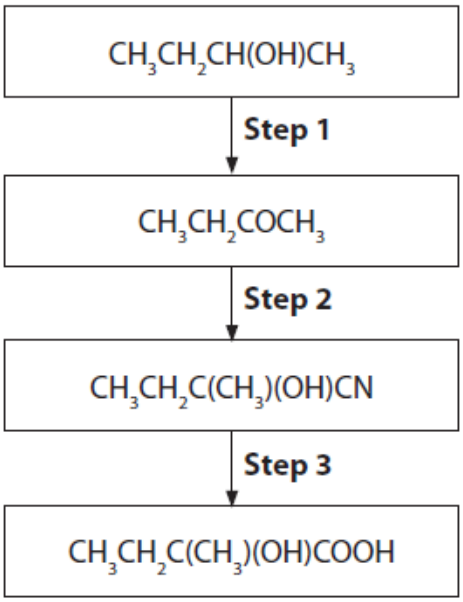
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**(Total for question = 3 marks)**

Q42.

A flow chart for making 2-hydroxy-2-methylbutanoic acid from butan-2-ol is show below.




(a) (i) Give the reagents and conditions for **Step 1**.

**(2)**

.....

.....

.....

(ii) Butanone is formed in **Step 1**.

Give a chemical test to identify the carbonyl group and a further test to show the presence of the $H_3C-\overset{\overset{O}{\|}}{C}-$ group.

For both tests, give the observations that you would make.

**(4)**

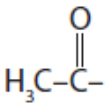
Carbonyl group

.....

.....

.....

.....

 group

.....

.....

.....

.....

(b) (i) In **Step 2**, butanone undergoes an addition reaction with HCN in the presence of $CN^-$ ions.

Give the mechanism for this reaction.

**(3)**

*(ii) By considering the mechanism of the reaction, explain why the addition of hydrogen cyanide to butanone gives a solution which has no effect on the plane of polarization of plane-polarized light.

**(3)**

.....

.....

.....

.....

.....

.....

(c) (i) Suggest the type of reaction occurring in **Step 3**.

**(1)**

.....

(ii) Explain why the presence of the alcoholic hydroxyl group cannot be confirmed in the infrared spectrum of 2-hydroxy-2-methylbutanoic acid.

**(1)**

.....

.....

(iii) The hydrogen of the alcohol group in 2-hydroxy-2-methylbutanoic acid can be identified by a single peak in the nmr spectrum.

Give the chemical shift you would expect for this peak.

**(1)**

.....

(iv) Explain why, in high resolution nmr, the peak due to the hydrogens of the 2-methyl group in 2-hydroxy-2-methylbutanoic acid is a singlet.

**(1)**

.....

.....

(d) Molecules of 2-hydroxy-2-methylbutanoic acid react together to form a condensation polymer.

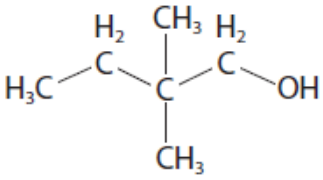
Draw a **displayed** formula for this polymer, showing two repeating units.

**(2)**

**(Total for question = 18 marks)**

Q43.

The alcohol 2,2-dimethylbutan-1-ol has the structure




Devise a reaction scheme for a synthesis of this alcohol starting from 2-bromo-2-methylbutane. Include in your answer all reagents and conditions and the structures of any intermediate compounds.

**(6)**

**(Total for question = 6 marks)**

Q44.

**Benzene**

Benzene was first discovered by Michael Faraday in London in 1825. He identified it by distilling a liquid obtained from condensing a gas produced by heating whale oil.

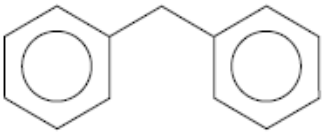
In 1834, Mitscherlich discovered the same liquid could be obtained by heating benzoic acid with lime.

Benzene is now produced from petroleum. Petroleum is fractionally distilled and benzene is obtained from the hexane in the naphtha fraction.

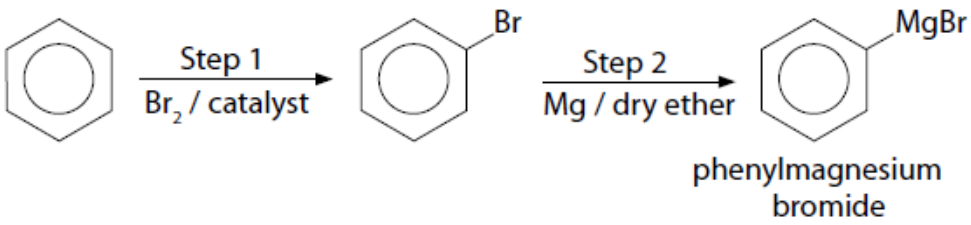
Hexane is heated to about 770 K. It then passes to a reactor where it reacts to form cyclohexane and hydrogen. The cyclohexane is then dehydrogenated to form benzene. Other aromatic products like methylbenzene and dimethylbenzenes are also produced. The aromatic products are separated by further distillation.

Benzene is the starting compound for a large number of useful chemicals and materials. For example it is used to make the polymer, poly(phenylethene).

Diphenylmethane is used to provide the geranium fragrance in soap.



It can be synthesised in five steps from benzene. The first two steps in the process are




(i) Name the catalyst in Step 1.

**(1)**

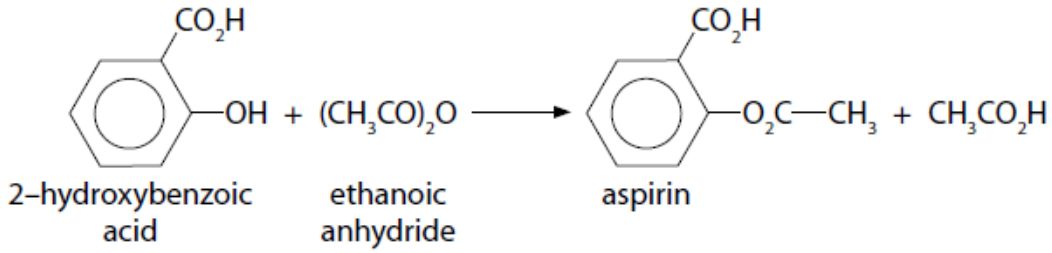
(ii) Write a three step synthesis to convert phenylmagnesium bromide to diphenylmethane, including reagents used in each step.

**(6)**

Q45.

This question is about the chemistry of the alcohol functional group.

The painkiller aspirin can be synthesised by the reaction between 2-hydroxybenzoic acid, which contains a hydroxyl group, and ethanoic anhydride, using concentrated phosphoric acid as a catalyst. The reagents are heated under reflux, then the excess ethanoic anhydride is removed by reacting it with water.




2–hydroxybenzoic acid | ethanoic anhydride | aspirin

(i) The percentage yield for this synthesis is 65%.

Calculate the mass of aspirin you would obtain using 2.0 g of 2-hydroxybenzoic acid.

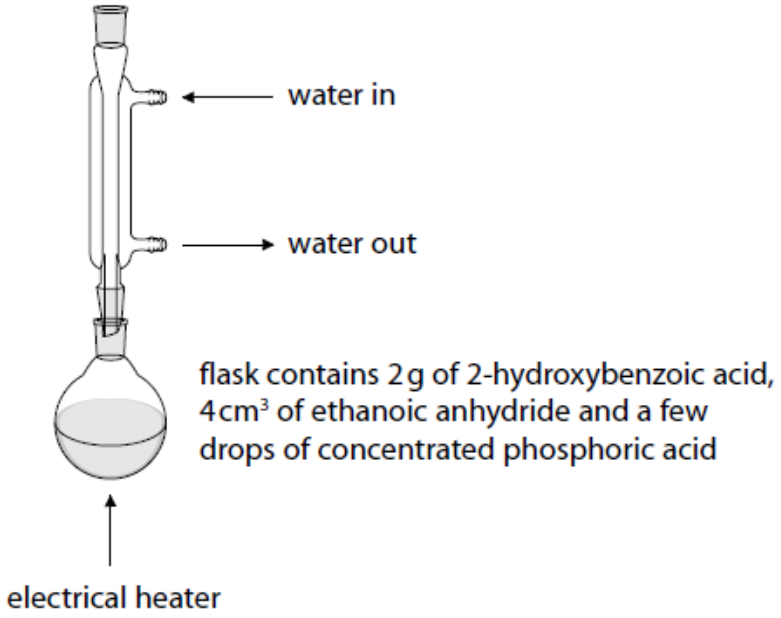
**(3)**

(ii) The diagram shows a proposed set-up of apparatus used for the stage of the synthesis that requires heating under reflux.

Identify **three** improvements that should be made to this set-up. Give a reason for each improvement made.

You may assume suitable clamps are used.

**(6)**




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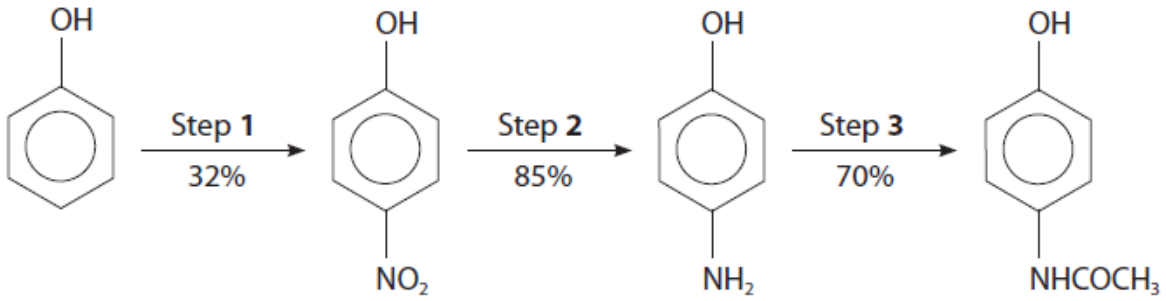
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Q46.

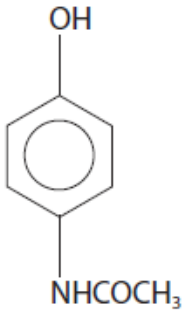
**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

The painkiller paracetamol can be synthesised from phenol in three steps.
The percentage yield for each step is shown.

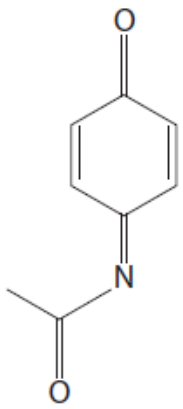



phenol paracetamol

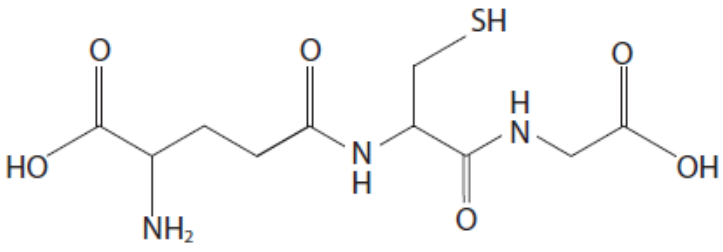
When metabolised in the body, paracetamol forms a toxic compound **Z**.
This is then removed in the liver by a reaction with the tripeptide glutathione.




paracetamol




compound **Z**




glutathione

(i) The conversion of paracetamol to compound **Z** is

(1)

☒ **A** addition

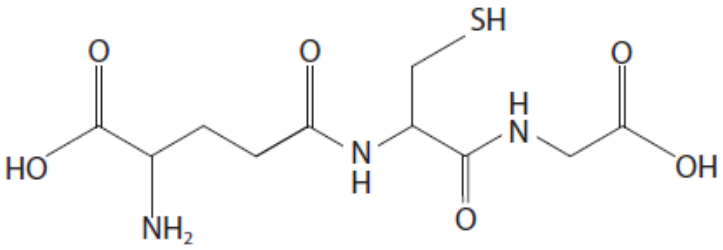
☒ **B** hydrolysis

☒ **C** oxidation

☒ **D** reduction

(ii) Draw a circle around each of the chiral carbon atoms in glutathione.

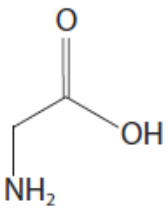
(1)



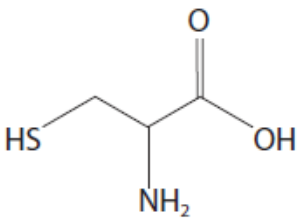

(iii) Glutathione is formed from glycine and two other amino acids.

Which two amino acids combine with glycine to form glutathione?

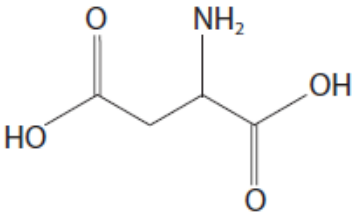
(1)



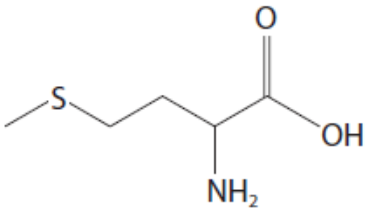

glycine



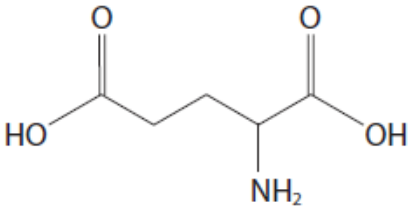

cysteine




aspartic acid




methionine




glutamic acid

☒ **A** aspartic acid and cysteine

☒ **B** glutamic acid and cysteine

☒ **C** glutamic acid and methionine

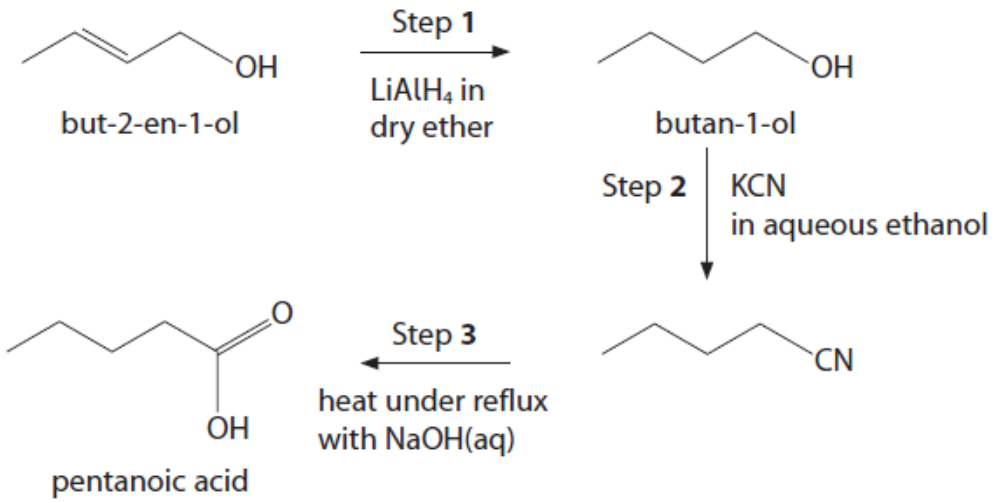
☒ **D** aspartic acid and methionine

**(Total for question = 4 marks)**

Q47.

This question is about the synthesis of organic compounds.

A student suggested the following plan for the synthesis of pentanoic acid from but-2-en-1-ol.




(i) $LiAlH_4$ is a source of hydride ions, $H^-$.

Give a possible reason why $LiAlH_4$ cannot be used to reduce alkenes.

**(1)**

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(ii) Give a suitable reagent and condition for Step **1**.

**(2)**

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(iii) Step **2** is incorrect because alcohols can only be converted to nitriles via an intermediate compound.

Identify a suitable intermediate compound by name or formula.

**(1)**

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(iv) Step **3** involves the hydrolysis of a nitrile.

Give the additional reagent that should be added after heating under reflux with aqueous sodium hydroxide, to produce
pentanoic acid.

**(1)**

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**(Total for question = 5 marks)**

Q48.

Propanoic acid can be synthesised from propene, a by-product of the petrochemical industry.

(a) Complete the equation to show the formation of propene and one other hydrocarbon.

$$C_{10}H_{22} \rightarrow C_3H_6 + .....$$

**(1)**

(b) Propanoic acid can be synthesised from propene in 3 steps. A student proposed the following synthesis:

Step 1: propene → 1-bromopropane

Step 2: 1-bromopropane → **X**

Step 3: **X** → propanoic acid

(i) Identify **X** and give the conditions needed to carry out Step 2 and Step 3 in this synthesis.

**(4)**

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(ii) Explain, by considering the mechanism of the reaction, why the student's choice of reaction for Step 1 will lead to a low overall yield.

**(2)**

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Q49.

Propanoic acid can be synthesised from propene, a by-product of the petrochemical industry.

Propene is used in the manufacture of polymers.

(i) Write an equation to show the formation of poly(propene) from propene.

**(2)**

(ii) Describe how the chemical reaction to form the polymer nylon differs from the chemical reaction to form poly(propene).

**(2)**

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(iii) Give **two** ways in which chemists contribute to a more sustainable use of such materials as poly(propene) and nylon.

**(2)**

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Q50.

This is a question about the hydrolysis of halogenoalkanes.

Explain the trend in the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

**(2)**

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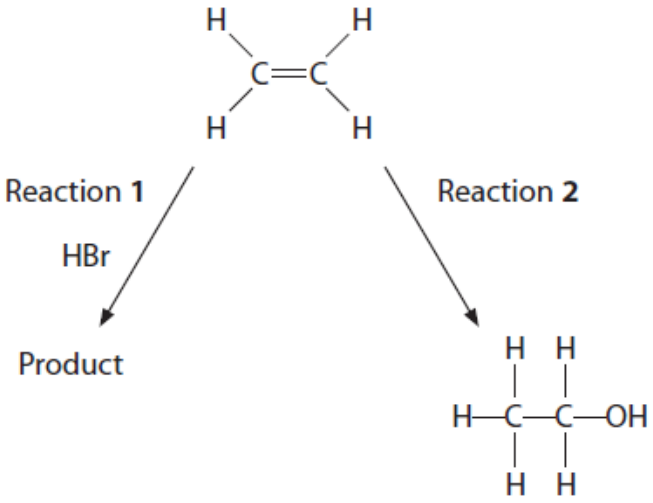
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**(Total for question = 2 marks)**

Q51.

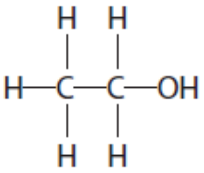
This question is about alkenes.

Two reactions of ethene are shown.




Complete the table.

**(3)**

| Reaction | Reagent and condition | Product |
|---|---|---|
| 1 | HBr at room temperature | |
| 2 | |  |

**(Total for question = 3 marks)**

Q52.

(a) This question is about the analysis of an unknown carboxylic acid **X** by three students.

The students analyse the mass spectrum of **X** and find that it has a molecular ion peak at $m / z =$ 116.

The three students each propose a different structural formula for compound **X**.

**Structure 1** HOOCCH==CHCOOH

**Structure 2** $HOCH_2CH==CHCH_2COOH$

**Structure 3** $CH_3CH_2CH_2CH_2CH_2COOH$

The students are given the infrared spectrum of **X**.

(i) State **two** wavenumber ranges of the infrared absorptions providing evidence that compound **X** is a carboxylic acid. Include the bonds responsible.

**(2)**

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(ii) One of the students suggests that this infrared spectrum and the data in the Data Booklet

**alone** could be used to identify which of the three proposed structures is **X**.

Show that this student's suggestion is correct. Include relevant infrared data in your answer.

**(3)**

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(b) The students decide to carry out an acid-base titration to obtain further information about compound **X**.

Each student uses solid sodium hydroxide, NaOH, to prepare a solution of concentration 0.140 mol $dm^{-3}$.

Calculate the mass, in grams, of solid sodium hydroxide that each student should weigh out to prepare 250.0 $cm^3$ of a 0.140 mol $dm^{-3}$ solution.

**(2)**

(c) Each of the students makes up 250.0 $cm^3$ of 0.140 mol $dm^{-3}$ sodium hydroxide solution in a volumetric flask and titrates this solution with the same solution of **X** of known concentration.

**Student A**

- correctly prepares the 0.140 mol $dm^{-3}$ sodium hydroxide solution and pipettes a volume of 10.0 $cm^3$ of the solution into a conical flask
- fills a burette with the solution of **X** and carries out a titration
- repeats the procedure until obtaining concordant results
- obtains a mean titre of 10.20 $cm^3$.

**Student B**

- dissolves the sodium hydroxide in distilled water and transfers the solution to a volumetric flask
- adds more distilled water to the volumetric flask and mixes the solution
- notices that the volumetric flask has been filled with distilled water several $cm^3$ beyond the graduation mark

- realises the mistake, removes the extra solution and discards it
- pipettes 10.0 $cm^3$ of the sodium hydroxide solution into a conical flask and titrates this with the solution of **X**.

**Student C**

- correctly prepares the 0.140 mol $dm^{-3}$ sodium hydroxide solution
- washes a conical flask thoroughly with distilled water and pipettes 10.0 $cm^3$ of the sodium hydroxide solution into the wet conical flask
- titrates the contents of the conical flask with the solution of **X**.

(i) Explain how, if at all, Student **B**'s mistake affects the value of the titre.

**(2)**

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(ii) Explain how, if at all, Student **C**'s use of a wet conical flask affects the value of the titre.

**(2)**

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(iii) Student **A** uses three pieces of apparatus to measure volumes in this experiment.

- The burette has an uncertainty of ±0.05 $cm^3$ for each volume reading
- The volumetric flask has an uncertainty of ±0.30 $cm^3$ for the volume
- The pipette has an uncertainty of ±0.04 $cm^3$ for the volume

Show by calculation which volume measurement has the lowest percentage uncertainty.

**(3)**

(d) Student **A** calculates the correct value for the molar mass of compound **X**, using the mean titre of 10.20 $cm^3$. The results indicate that **X** has **structure 1**.

**Structure 1** HOOCCH==CHCOOH

**Structure 2** $HOCH_2CH{=}{=}CHCH_2COOH$

**Structure 3** $CH_3CH_2CH_2CH_2CH_2COOH$

(i) Write the equation for the reaction between **structure 1** and sodium hydroxide solution. State symbols are not required.

**(2)**

(ii) Deduce the value that would have been obtained for the mean titre if the structural formula of **X** had been **structure 2**.

Justify your answer.

**(2)**

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(e) The students could have identified the three structures using chemical tests.

Complete the table to show whether or not the suggested structures react with bromine water and when heated with acidified potassium dichromate(VI).

Use a tick (✓) if a reaction occurs.

Use a cross (✗) if no reaction occurs.

**(2)**

| Structure | Test with bromine water | Test with acidified potassium dichromate(VI) |
|---|---|---|
| HOOCCH═CHCOOH | | |
| $HOCH_2CH═CHCH_2COOH$ | | |
| $CH_3CH_2CH_2CH_2CH_2COOH$ | | |

(f) The structure HOOCCH==CHCOOH has two stereoisomers.

(i) Draw the structures of these stereoisomers.

**(2)**

***E*-isomer**

***Z*-isomer**

(ii) State why HOOCCH==CHCOOH has *E*/*Z* isomers.

**(2)**

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**(Total for question = 24 marks)**

Q53.

This is a question about halogenoalkanes and related compounds.

In aqueous sodium hydroxide, 1-bromoethane reacts to produce ethanol.

(i) Write the mechanism for this reaction, including all relevant curly arrows, lone pairs and dipoles. Include the transition state.

**(4)**

(ii) Give the reagents that are used to test that bromide ions are formed in this reaction mixture. Include the result of the test.

**(2)**

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**(Total for question = 6 marks)**