F322: Chains, Energy and Resources

Basic Concepts

1. Some of the hydrocarbons in kerosene have the formula C\textsubscript{10}H\textsubscript{22}.

   (i) What is the name of the straight chain hydrocarbon with the formula C\textsubscript{10}H\textsubscript{22}?

   ..............................................................................................................................................

   [1]

   (ii) Draw the skeletal formula of one branched chain isomer with the formula C\textsubscript{10}H\textsubscript{22}.

   ..............................................................................................................................................

   [1]

   (iii) Explain why the straight chain isomer of C\textsubscript{10}H\textsubscript{22} has a higher boiling point than any of its branched chain structural isomers.

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   [2]

   (iv) Explain why the straight chain isomer of C\textsubscript{10}H\textsubscript{22} is converted by the petroleum industry into its branched chain isomers.

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   [1]

   [Total 5 marks]
2. (i) In the past, hydrogen peroxide was manufactured by reacting barium peroxide, \( \text{BaO}_2 \), with ice-cold dilute sulfuric acid.

\[
\text{BaO}_2(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + \text{H}_2\text{O}_2(\text{aq})
\]

This method required the disposal of poisonous barium compounds.

Calculate the atom economy for this manufacture of hydrogen peroxide from \( \text{BaO}_2 \).
Use the table of relative formula masses given below.

<table>
<thead>
<tr>
<th>compound</th>
<th>relative formula mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{BaO}_2 )</td>
<td>169.3</td>
</tr>
<tr>
<td>( \text{H}_2\text{SO}_4 )</td>
<td>98.1</td>
</tr>
<tr>
<td>( \text{BaSO}_4 )</td>
<td>233.4</td>
</tr>
<tr>
<td>( \text{H}_2\text{O}_2 )</td>
<td>34.0</td>
</tr>
</tbody>
</table>

\[
\text{atom economy} = \frac{2 \times 169.3}{169.3 + 98.1 + 233.4 + 34.0}
\]

[2]
(ii) Nowadays, hydrogen peroxide is manufactured using hydrogen gas, oxygen from the air and a substance called anthraquinone.

**stage 1** \[ H_2 + \text{anthraquinone} \rightarrow \text{anthraquinol} \]

**stage 2** \[ O_2 + \text{anthraquinol} \rightarrow H_2O_2 + \text{anthraquinone} \]

Compare the manufacture of \( H_2O_2 \) from hydrogen and oxygen with the manufacture from barium peroxide described in (i).

Explain the advantages of the manufacture of \( H_2O_2 \) from hydrogen and oxygen.

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[3]  
[Total 5 marks]

3. The ‘curly arrows’ model is used in reaction mechanisms to show the movement of electron pairs during chemical reactions.

Choose a reaction mechanism that you have studied involving the curly arrow model.

Name and describe your chosen reaction mechanism.

In your answer, include:

- an example of the reaction with the chosen mechanism,
- the type of bond fission that occurs,
- relevant dipoles.

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[Total 6 marks]
4. Draw the skeletal formula for 2-methylpentan-3-ol.

[Total 1 mark]

5. Butan-2-ol and 2-methylpropan-2-ol are structural isomers.
   (i) What is meant by the term *structural isomer*?

   ..................................................................................................................................
   ..................................................................................................................................
   ..................................................................................................................................

   [1]

   (ii) Draw another structural isomer of these two alcohols.

   ..................................................................................................................................
   ..................................................................................................................................

   [1]
   [Total 2 marks]

6. Crude oil is a source of hydrocarbons which can be used as fuels or for processing into petrochemicals.

   Octane, $\text{C}_8\text{H}_{18}$, is one of the alkanes present in petrol.

   Carbon dioxide is formed during the complete combustion of octane.

   $$\text{C}_8\text{H}_{18} + 12\frac{1}{2}\text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O}$$

   What is the general formula for an alkane?

   ..................................................................................................................................

   [Total 1 mark]
7. Oil companies process hydrocarbons, such as octane, into branched and cyclic hydrocarbons that promote efficient combustion in petrol.

Draw the skeletal formulae of a branched hydrocarbon and a cyclic hydrocarbon, each containing eight carbon atoms.

[Total 2 marks]

8. Alkenes can be prepared by the dehydration of alcohols with an acid catalyst. Cyclohexene can be prepared by the dehydration of cyclohexanol, shown below.

\[
\begin{align*}
\text{OH} & \quad \rightarrow \\
\text{H} & \quad \text{H} \\
\text{C}_6\text{H}_{12} & \quad + \quad \text{H}_2\text{O}
\end{align*}
\]

A student reacted 7.65 g of cyclohexanol, \( \text{C}_6\text{H}_{12}\text{O} \), and obtained 0.0268 mol of cyclohexene.

(i) What is the molecular formula of cyclohexene?

.......................................................................................................................................................... [1]

(ii) Calculate the percentage yield of cyclohexene.

\[
\text{answer} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 \%
\]

.................................................................................................................................................. [3]

[Total 4 marks]

9. Percentage yield has been used for many years to measure the ‘success’ of a reaction. Recently, chemists have turned their thoughts also to the atom economy of a reaction.

(i) Explain the term atom economy.

..........................................................................................................................................................
.......................................................................................................................................................... [1]
(ii) Alkenes can be prepared by the dehydration of alcohols with an acid catalyst. Cyclohexene can be prepared by the dehydration of cyclohexanol, shown below.

\[
\begin{array}{c}
\text{OH} \\
\text{H}_2\text{O}
\end{array}
\rightarrow
\begin{array}{c}
\text{Cyclohexene}
\end{array}
\]

Cyclohexene can also be prepared by the reaction below.

\[
\text{Cyclohexene} + \text{H}_2\text{O} \rightarrow \text{Cyclohexene}
\]

Explain why the atom economy of this cyclohexene preparation is higher than that from cyclohexanol.

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[2]
[Total 3 marks]

10. In this question, you are asked to suggest structures for several organic compounds.

Compounds F, G and H are unbranched alkenes that are isomers, each with a relative molecular mass of 70.0.

Compounds F and G are E/Z stereoisomers.

Compound H is a structural isomer of compounds F and G.

• Explain what is meant by the terms structural isomer and stereoisomer.

• Explain why some alkenes have E/Z isomerism.

• Analyse this information to suggest possible structures for compounds F, G and H.
In your answer you should make clear how each structure fits with the information given above.

[Total 11 marks]

11. Predict the molecular formula of an alkane with 13 carbon atoms.

[Total 1 mark]
12. Bromobutane, CH₃CH₂CH₂CH₂Br, can be reacted with hot aqueous sodium hydroxide to prepare butan-1-ol.

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{Br}^-
\]

A student reacted 8.72 g of bromobutane with an excess of OH⁻. The student produced 4.28 g of butan-1-ol.

(i) Calculate the amount, in mol, of CH₃CH₂CH₂CH₂Br reacted.

\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}, \text{Mr} = 136.9\]

................................................. mol \[1\]

(ii) Calculate the amount, in mol, of CH₃CH₂CH₂CH₂OH produced.

................................................. mol \[2\]

(iii) Calculate the percentage yield.

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

................................................. % \[1\]

[Total 4 marks]
13. But-1-ene is just one isomer with the molecular formula C_4H_8.

Using C_4H_8 as your example, describe and explain what is meant by structural isomerism and *cis-trans* isomerism.

Include diagrams in your answer.

In your answer you should make clear how each type of isomerism is related to structural features.

[Total 7 marks]

14. In this question, one mark is available for the quality of use and organisation of scientific terms.

- Describe, with the aid of a suitable diagram, the formation of the π-bond in propene.
- State the shape, and an approximate value for the bond angles, around each carbon atom in propene.
- Describe, with the aid of a suitable example, why some alkenes show *cis-trans* isomerism.

[9]

Quality of Written Communication [1]

[Total 10 marks]

15. Cyclohexane and cyclohexene are both cyclic hydrocarbons.

![Cyclohexane and Cyclohexene](image)

- What is the molecular formula of cyclohexene? ............................................

  [1]

- What is the empirical formula of cyclohexene? ..............................................

  [1]
(iii) Calculate the percentage, by mass, of carbon in cyclohexene. Give your answer to two significant figures.

answer ...............................................

[Total 4 marks]

16. Halogenoalkanes are used in the production of pharmaceuticals, polymers and flame retardants.

1-Bromo-2-methylpropane is used in the production of ibuprofen and can be prepared from the reaction between 2-methylpropan-1-ol and HBr.

\[(\text{CH}_3\text{)}_2\text{CHCH}_2\text{OH} + \text{HBr} \rightarrow (\text{CH}_3\text{)}_2\text{CHCH}_2\text{Br} + \text{H}_2\text{O}\]

A student reacted 4.44 g of 2-methylpropan-1-ol with an excess of HBr. The student produced 5.48 g of 1-bromo-2-methylpropane.

(i) Calculate the number of moles of \((\text{CH}_3\text{)}_2\text{CHCH}_2\text{OH}\) used.

answer ............................ mol

[2]

(ii) Calculate the number of moles of \((\text{CH}_3\text{)}_2\text{CHCH}_2\text{Br}\) collected.

\((\text{CH}_3\text{)}_2\text{CHCH}_2\text{Br}, \text{M}_r = 137\)

answer ............................ mol

[1]

(iii) Calculate the percentage yield. Quote your answer to three significant figures.

answer ............................

[1]

[Total 4 marks]
17. In this question, one mark is available for the quality of use and organisation of scientific terms.

Name and give examples of the types of isomerism in compounds with formula C₄H₈. Explain how each type of isomerism arises.

[8]
Quality of Written Communication [1]
[Total 9 marks]

18. Propane, C₃H₈, is used in the reaction sequence shown below.

H₃C—CH₂—CH₃ reaction 1 H₃C—CH₂—CH₂—Cl
Cl₂/uv light

reaction 2 H₃C—CH₂—CH₂—OH
aqueous OH⁻/ heat

reaction 3 H₃C—CH=CH₂
ethanolic OH⁻/ heat

reaction 4

(a) The reaction sequence shows several important reaction mechanisms. Select from reactions 1 to 4, the reaction that shows

(i) free radical substitution, reaction .......... [1]

(ii) electrophilic addition, reaction .......... [1]

(iii) elimination, reaction .......... [1]

(b) In reaction 2, the aqueous OH⁻ acts as a nucleophile.

(i) State what is meant by the term nucleophile.
............................................................................................................................................................................................................................................................................................................ [1]

(ii) Complete, with the aid of curly arrows, the mechanism involved in reaction 2. Show any relevant dipoles.

H₃C—CH₂—CH₂—Cl → H₃C—CH₂—CH₂—OH + ..........

OH⁻

[4]
(c) Compounds B and D are structural isomers of each other.

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

................................................................................................................
................................................................................................................

[2]

(ii) Draw the skeletal formulae of compounds B and D.

<table>
<thead>
<tr>
<th>Compound B</th>
<th>Compound D</th>
</tr>
</thead>
</table>

[2]

(d) Compound C can be polymerised to form compound E.

(i) State the type of polymerisation. ............................................................

[1]

(ii) Name compound E. .............................................................................

[1]

(iii) Draw a section of compound E. Show **two** repeat units.

[1]

[Total 15 marks]
19. This question is about the compounds A-F below.

(a) Answer the following questions by referring to the compounds A-F.

(i) What is the molecular formula of compound D?
................................................................................................................ [1]

(ii) What is the empirical formula of compound C?
................................................................................................................ [1]

(iii) Which two compounds are structural isomers of each other?
................................................................................................................ [1]

(iv) Which two compounds are cis-trans isomers of each other?
................................................................................................................ [1]
(b) Compound **E** can be dehydrated to form compound **A**. Complete a balanced equation for this reaction.

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \rightarrow \\
\text{H} & \quad \text{H} & \quad \text{OH} & \quad \text{H}
\end{align*}
\]

[1]

(c) Compound **C** can be dehydrated to form a new compound, **G**, with the molecular formula, \(C_4H_6\). Suggest a structural formula and a name for **G**.

name ...........................................................................................................................................

[2]

[Total 7 marks]

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20. (a) Many organic molecules show structural isomerism. State what is meant by the term **structural isomerism**.

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[2]

(b) Isomers 1, 2 and 3, shown below, are unsaturated structural isomers of \(C_5H_{10}\).

<table>
<thead>
<tr>
<th>(\text{CH}_3\text{CH}_2\text{C}==\text{C} )</th>
<th>(\text{CH}_3\text{CH}==\text{C} )</th>
<th>(\text{H}_5\text{C}==\text{C} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>isomer 1</td>
<td>isomer 2</td>
<td>isomer 3</td>
</tr>
<tr>
<td>(\text{CH}_3\text{CH}_2\text{H} )</td>
<td>(\text{CH}_3\text{H} )</td>
<td>(\text{CH}_3\text{H} )</td>
</tr>
</tbody>
</table>

(i) Complete the boxes by drawing two other unsaturated structural isomers of \(C_5H_{10}\).
21. There are several cycloalkanes that are structural isomers of $C_5H_{10}$.

(i) Complete the boxes by drawing two other structural isomers of $C_5H_{10}$ that are also cycloalkanes.

<table>
<thead>
<tr>
<th>Isomer $L$</th>
<th>ethylcyclopropane</th>
</tr>
</thead>
</table>

(ii) Name isomer $L$ drawn in (i).

..........................................................................................................................................................................

(iii) Draw the skeletal formula of isomer $L$.

..........................................................................................................................................................................

[Total 6 marks]
Lavandulol, $C_{10}H_{18}O$, is a fragrant oil which is found in lavender. The structural and the skeletal formulae of lavandulol are shown below.

(a) (i) Identify two different functional groups in lavandulol.

.................................................. and ......................................................  

(ii) Why does lavandulol not have cis-trans isomerism?

................................................................................................................

................................................................................................................  

(b) Lavandulol, $C_{10}H_{18}O$, also reacts with bromine to form a saturated organic product.

State what you would see in this reaction and deduce the molecular formula of the organic product.

observation .....................................................................................................  

molecular formula ...........................................................................................
(c) Lavandulol could be converted into an ester $X$, which is also found in lavender oil.

![ester X]

State a reagent and a catalyst that could be used to form ester $X$ from lavandulol.

reagent ............................................................................................................ [1]
catalyst ............................................................................................................ [1]

(d) Lavandulol can be oxidised to produce either compound $Y$ or compound $Z$.

![compound Y]

![compound Z]

lavandulol $\text{C}_{10}\text{H}_{18}\text{O}$

compound $Y$ $\text{C}_{10}\text{H}_{16}\text{O}$

compound $Z$ $\text{C}_{10}\text{H}_{16}\text{O}_2$
(i) Write a balanced equation for the oxidation of lavandulol to produce compound Z. Use the molecular formulae given above and use [O] to represent the oxidising agent.

................................................................................................................

[2]

(ii) An infra-red spectrum of either compound Y or compound Z was obtained and was found to contain an absorption between 1680 – 1750 cm\(^{-1}\). However, there was no broad absorption between 2500 – 3300 cm\(^{-1}\).

By referring to your Data Sheet, use this information to deduce whether the infra-red spectrum was of compound Y or of compound Z. Show your reasoning.

The infra-red spectrum was of compound .......... because ..............

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[2]

[Total 12 marks]