This Support Material booklet is designed to accompany the OCR GCE Chemistry A Specimen Paper F322 for teaching from September 2008.
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Introduction

OCR has produced these candidate style answers to support teachers in interpreting the assessment criteria for the new GCE specifications and to bridge the gap between new specification release and availability of exemplar candidate work.

This content has been produced by senior OCR examiners, with the input of Chairs of Examiners, to illustrate how the sample assessment questions might be answered and provide some commentary on what factors contribute to an overall grading. The candidate style answers are not written in a way that is intended to replicate student work but to demonstrate what a “good” or “excellent” response might include, supported by examiner commentary and conclusions.

As these responses have not been through full moderation and do not replicate student work, they have not been graded and are instead, banded “medium” or “high” to give an indication of the level of each response.

Please note that this resource is provided for advice and guidance only and does not in any way constitute an indication of grade boundaries or endorsed answers.
Question 1

1 The table below lists the boiling points of some alkanes.

<table>
<thead>
<tr>
<th>alkane</th>
<th>number of carbon atoms</th>
<th>molecular formula</th>
<th>boiling point °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>butane</td>
<td>4</td>
<td>C₄H₁₀</td>
<td>0</td>
</tr>
<tr>
<td>pentane</td>
<td>5</td>
<td>C₅H₁₂</td>
<td>36</td>
</tr>
<tr>
<td>hexane</td>
<td>6</td>
<td>C₆H₁₄</td>
<td>69</td>
</tr>
<tr>
<td>heptane</td>
<td>7</td>
<td>C₇H₁₆</td>
<td>99</td>
</tr>
<tr>
<td>octane</td>
<td>8</td>
<td>C₈H₁₈</td>
<td></td>
</tr>
<tr>
<td>nonane</td>
<td>9</td>
<td>C₉H₂₀</td>
<td>152</td>
</tr>
<tr>
<td>decane</td>
<td>10</td>
<td>C₁₀H₂₂</td>
<td>175</td>
</tr>
</tbody>
</table>

(a) (i) Predict the boiling point of octane. [1]

120

(ii) State and explain the trend in the boiling points of these alkanes. [2]

*As the alkane gets bigger the boiling point goes up.*

(b) Predict the molecular formula of an alkane with 13 carbon atoms. [1]

C₁₃H₂₈

(c) Long chain alkanes, such as nonane, are cracked into shorter chain alkanes and alkenes.

Write a balanced equation for the cracking of nonane into heptane and ethene. [1]

C₉H₂₀ → C₇H₁₆ + C₂H₄
(d) Straight chain alkanes such as heptane, C\textsubscript{7}H\textsubscript{16}, are processed into branched-chain alkanes and cyclic compounds. These products are required to make petrol burn better in car engines than when using unbranched alkanes.

(i) Draw the skeletal formula of a branched structural isomer of heptane and state its name.

skeletal formula: \[2,2,3\text{-trimethylbutane}\]

(ii) Write a balanced equation to show the formation of the cyclic compound methylcyclohexane from heptane.

(e) Butane, C\textsubscript{4}H\textsubscript{10}, reacts with chlorine to produce a chloroalkane with molecular formula C\textsubscript{4}H\textsubscript{9}Cl.

The reaction is initiated by the formation of chlorine radicals from chlorine.

(i) What is meant by the term \textit{radical}?

An atom with a single electron

(ii) State the conditions necessary to bring about the formation of the chlorine free radicals from Cl\textsubscript{2}.

\[UV\]

(iii) State the type of bond fission involved in the formation of the chlorine radicals.

\[Heterolytic\]

(iv) The chlorine radicals react with butane in several steps to produce C\textsubscript{4}H\textsubscript{9}Cl.

Write equations for the two propagation steps.

\[\text{Cl.} + \text{C}_4\text{H}_{10} \rightarrow \text{C}_4\text{H}_9. + \text{HCl}\]

\[\text{C}_4\text{H}_9. + \text{Cl.} \rightarrow \text{C}_4\text{H}_9\text{Cl}\]
Comments

“120” is just in range in (a) (i), but “bigger” is too vague in (ii) and there is no explanation. (iii) is correct, as is the equation in (b). In (d) the candidate has a correct skeletal formula in both parts, but has forgotten the other, simpler, product, hydrogen. In (e), “single” is too ambiguous and “heterolytic” is the wrong type of fission. The first equation is correct, but then they give a termination equation rather than the other chain reaction.

Question 2 (a)

2 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) 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.

\[
\text{Moles} = \frac{8.72}{123} = 0.0709 \text{ mol} 
\]

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

\[
\text{Moles} = \frac{4.28}{74} = 0.0578 \text{ mol} 
\]

(iii) Calculate the percentage yield.

Quote your answer to three significant figures.

\[
\% = \frac{0.0709}{0.0637} \times 100 = 111 \%
\]

Comments

The first part is incorrect: in fact there are two errors, the rfm has missed out one of the CH₂ units and bromine has been taken as 80, whereas it is 79.9 on the Periodic Table for the new spec. The candidate should have checked their working, as a yield of over 100% seems improbable! However, all the other marks are awarded consequentially.
Question 2 (b)

(b) In this reaction the hydroxide ion acts as a nucleophile.

(i) What name is given to this type of reaction?

Substitution

(ii) Explain the term nucleophile.

A nucleus lover

(iii) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

Comments

The first two parts are for simple recall; however, the definition given in (ii) is not the one we expect at AS level. The mechanism is also straightforward, straight from the specification with only a longer carbon chain. The candidate has ignored this and used bromoethane! The first curly arrow is going the wrong way, but everything else is correct. This is a typical answer from a student who has nearly remembered the mechanism, but never understood it.

Question 2 (c)

(c) The butan-1-ol produced in (a) can be analysed by mass spectrometry.

(i) Predict two fragment ions that you would expect to see in the mass spectrum of butan-1-ol and state the \( m/z \) value of each ion.

\( \text{C}_3\text{H}_7^+ \) at 29  \( \text{OH}^- \) at 17

(ii) State a use of mass spectrometry outside of the laboratory.

Analysing things
Comments

The first fragment ion is correct, but there are no negatively charged fragments detected in a mass spectrometer. The answer to (ii) is too vague.

Question 3 (a)

3 Ethanol, C₂H₅OH, is manufactured on a large scale for a wide range of uses such as alcoholic drinks, as an industrial solvent and as a raw material for the synthesis of many organic compounds.

(a) Ethanol, C₂H₅OH, is manufactured on a large scale by two methods:

- Fermentation, using yeast, of sugars, such as glucose, C₆H₁₂O₆.

  \[ \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \underset{}{\rightarrow} 2\text{C}_2\text{H}_5\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g}) \]

  The ethanol is then distilled off.

- Hydration of ethene, C₂H₄, with steam in the presence of an acid catalyst.

  \[ \text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \underset{}{\rightarrow} \text{C}_2\text{H}_5\text{OH}(\text{g}) \]

Compare the sustainability of these methods of manufacturing ethanol in terms of:

- availability of starting materials and energy requirements;
- atom economy.

In your answer, you should make clear how the atom economy of the processes links with chemical theory.

Ethanol is made by fermentation of stuff that can be grown, this is good for the world because we can always grow more.

Ethene cannot be grown.

Ethene needs separating and cracking which uses lots of energy.

Ethene has a better atom economy as ethanol is the only product. Fermentation makes carbon dioxide which is a greenhouse gas and very bad for us.
Comments

The candidate has realised that sugar is a renewable resource, but has been too vague as to where ethene comes from. They have mentioned the energy requirement in the production of ethanol from ethene. The discussion of atom economy is again very vague, but they have said that ethene produces only ethanol as a product, whilst fermentation also produces carbon dioxide. The greenhouse effect is not relevant here. No use is suggested for the carbon dioxide and neither of the percentage atom economies are given.

Question 3 (b)

In the laboratory, ethanol can be oxidised with acidified potassium dichromate(VI).

(b) The ethanol can be oxidised to form either ethanal, CH₃CHO (Fig. 3.1), or ethanoic acid, CH₃COOH (Fig. 3.2).

![Fig. 3.1](image1.png) ![Fig. 3.2](image2.png)

The boiling points of ethanol, ethanal and ethanoic acid are given in the table below.

<table>
<thead>
<tr>
<th></th>
<th>CH₃CH₂OH</th>
<th>CH₃CHO</th>
<th>CH₃COOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>boiling point / °C</td>
<td>78</td>
<td>21</td>
<td>118</td>
</tr>
</tbody>
</table>

Use this table of boiling points to explain:
(i) why the organic product is likely to be ethanal if the apparatus shown in Fig. 3.1 is used,

Ethanal is formed when you use distillation.

(ii) why the organic product is likely to be ethanoic acid if the apparatus shown in Fig. 3.2 is used.

This is reflux, so ethanoic acid will be formed.

Comments

The candidate is doing little more than repeating the question.

Question 3 (c)

(c) Write a balanced equation for the oxidation of ethanol to ethanoic acid. Use \([O]\) to represent the oxidising agent.

\[
C_2H_5OH + [O] \rightarrow C_2H_5OOH
\]

Comments

Nothing worthy of any credit.

Question 3 (d)

(d) The ethanal collected using the apparatus shown in Fig. 3.1 was analysed by infrared spectroscopy.

Use your Data Sheet to justify which of the three spectra shown below is most likely to be that of ethanal.
(b) The organic product collected when using the apparatus shown in Fig. 3.1 is most likely to be that shown by spectrum ....

C

Because ...

*It has a C=O peak but no O-H peak*

*It is the aldehyde.*
Comments

It is correctly identified as the alcohol and the correct peaks are given, but there is no mention of wave numbers.

Question 4 (a)

4 Enthalpy changes of reaction can be determined indirectly from average bond enthalpies and standard enthalpy changes.

(a) The table below shows the values of some average bond enthalpies.

<table>
<thead>
<tr>
<th>bond</th>
<th>average bond enthalpy /kJ mol⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>C–H</td>
<td>+410</td>
</tr>
<tr>
<td>O–H</td>
<td>+465</td>
</tr>
<tr>
<td>O=O</td>
<td>+500</td>
</tr>
<tr>
<td>C=O</td>
<td>+805</td>
</tr>
<tr>
<td>C–O</td>
<td>+336</td>
</tr>
</tbody>
</table>

(i) Why do bond enthalpies have positive values? [1]

Breaking a bond is endothermic.

(ii) The equation below shows the combustion of methanol, CH₃OH, in the gaseous state.

\[
\text{CH}_3\text{OH}(g) + 1\frac{1}{2}\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(g)
\]

Using the average bond enthalpies in the table above, calculate the enthalpy change of combustion, \(\Delta H_c\), of gaseous methanol. [3]

\[
\begin{align*}
\text{Bond breaking} &= 3 \times 410(\text{C–H}) + 336(\text{C–O}) + 465(\text{O–H}) + 1.5 \times 500(\text{O=O}) = 2781 \text{ kJ} \\
\text{Bond making} &= -\left( 2 \times 805(\text{C=O}) + 2 \times 465(\text{O–H}) \right) = -2540 \\
\text{Energy change} &= 2781 - 2540 = 241 \text{ kJ mol}^{-1}
\end{align*}
\]
The definition is correct. The calculation all correct except that the O-H bond has only been multiplied by 2 rather than 4. As this is only one error, other marks would be awarded consequentially.

Question 4 (b)

(b) Methane reacts with steam to produce carbon monoxide and hydrogen. The equation for this process is given below.

\[ \text{CH}_4 (g) + \text{H}_2\text{O}(g) \rightarrow \text{CO}(g) + 3\text{H}_2(g) \]

The table below shows the standard enthalpy changes of formation for CH\(_4\), H\(_2\)O and CO.

<table>
<thead>
<tr>
<th>compound</th>
<th>( \Delta H^\circ ) /kJ mol(^{-1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH(_4)</td>
<td>-75</td>
</tr>
<tr>
<td>H(_2)O</td>
<td>-242</td>
</tr>
<tr>
<td>CO</td>
<td>-110</td>
</tr>
</tbody>
</table>

(i) Define the term enthalpy change of formation. \[2\]

The energy change when 1 mole of a substance is formed

(ii) In \( \Delta H^\circ \), what are the conditions indicated by the symbol \( ^\circ \)? \[1\]

Room temperature and pressure

(iii) Write the equation, including state symbols, that represents the standard enthalpy change of formation for carbon monoxide, CO. \[2\]

\[ 2\text{C}(s) + \text{O}_2(g) \rightarrow 2\text{CO}(g) \]

(iv) Using the \( \Delta H^\circ \) values in the table above, calculate the enthalpy change for the reaction of methane with steam.

\[ \text{CH}_4(g) + \text{H}_2\text{O}(g) \rightarrow \text{CO}(g) + 3\text{H}_2(g) \]

\[ \text{Enthalpy change} = \Delta H^\circ \text{CO} + 3\Delta H^\circ \text{H}_2 - \Delta H^\circ \text{CH}_4 - \Delta H^\circ \text{H}_2\text{O} \]

\[ = -110 + 3(-75) -(-242) \]

\[ = +207 \text{ kJ mol}^{-1} \]
(i) and (ii) are incorrect. The equation is correct, but has been doubled, when the definition refers to one mole of the product. This is one of the few cases where multiples are not acceptable. The state symbols are correct. The calculation is fine and well set out.

**Question 4 (c)**

(c) State one important manufacturing process in which hydrogen is used.  

*Hardening oils in margarine*

**Comments**

Correct.

**Question 5 (a)**

5 Nitrogen dioxide, NO₂, and dinitrogen tetroxide, N₂O₄, take part in the following equilibrium.

\[
2\text{NO}_2(g) \rightleftharpoons \text{N}_2\text{O}_4(g) \quad \Delta H = -58 \text{ kJ mol}^{-1}
\]

(a) State le Chatelier's principle.  

*When the temperature in an equilibrium is increased it goes down again.*  
*The same for pressure.*

**Comments**

Too vague to merit any marks.
Question 5 (b)

(b) Describe, and explain, what would happen to the position of the NO₂/N₂O₄ equilibrium if the following changes are made.

(i) The temperature is increased. [2]

*The equilibrium will move in the endothermic reaction, towards the left to make the temperature go down again. It moves to the left making more NO₂.*

(ii) The pressure is increased. [2]

*The equilibrium will move to which way makes the pressure go back down.*

(iii) A catalyst is added. [2]

*The equilibrium will not change.*

Comments

*This candidate is struggling with equilibrium! The first answer covers the main points, but the second does not really say anything of value. The catalyst answer says no change, but nothing else.*

Question 5 (c)

(c) The diagram below shows the energy distribution of molecules at a particular temperature. $E_a$ represents the activation energy of the reaction.

![Energy distribution diagram](image)

(i) On the diagram, draw a second curve to represent the energy distribution of the same number of molecules at a higher temperature. [2]
(ii) Using your completed diagram, explain how an increase in temperature causes the rate of reaction to increase. [2]

As the temperature gets higher more molecules have the activation energy as there is more space under the line after $E_a$.

Comments

The second curve starts well but then goes below the original line, which is incorrect. The explanation in the second part is still correct in terms of their own answer and would therefore pick up the marks consequentially.

Question 6 (a)

6 CFCs and carbon dioxide affect the Earth’s atmosphere.

(a) CFCs form chlorine radicals, Cl, in the atmosphere. Chlorine radicals are one of the factors responsible for depleting the ozone layer in the stratosphere.

The equations below represent two steps that occur during this process.

Complete these equations and construct an overall equation for the reaction. [2]

$$\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$$

$$\text{ClO} + \text{O} \rightarrow \text{Cl} + \text{O}_2$$

$$\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$$
**Question 6 (b)**

(b) Concern about the consumption of fossil fuels and excessive emissions of carbon dioxide from cars has led to moves to cut down on car usage.

(i) Heptane, C\(\text{\textsubscript{7}}\)H\(\text{\textsubscript{16}}\), is a component in petrol.

Construct a balanced equation for the complete combustion of heptane. [2]

\[
\text{C}_7\text{H}_{16} + 11\text{O}_2 \rightarrow 7\text{CO}_2 + 8\text{H}_2\text{O}
\]

(ii) Gases such as CO\(_2\) contribute towards the ‘Greenhouse Effect’.

What happens to CO\(_2\) molecules in this process? [2]

*They absorb infra-red radiation and radiate it again back down towards the earth.*

**Comments**

*The equation is correct and balanced. There is no mention of how the CO\(_2\) absorbs IR radiation.*

**Question 6 (c)**

(c) Two workers decide to car-share on a 25 mile journey to work and back. On this journey, each of their cars uses petrol equivalent to 2.0 kg of heptane.

Assuming such car-sharing, use your equation from b(i) to:

(i) calculate the amount, in mol, of heptane, C\(\text{\textsubscript{7}}\)H\(\text{\textsubscript{16}}\), saved; [2]

\[
mol = \frac{2}{100} = 0.020 \text{ mol}
\]

(ii) calculate the energy saved (\(\Delta H^\circ\) [C\(\text{\textsubscript{7}}\)H\(\text{\textsubscript{16}}\)] = −4817 kJ mol\(^{-1}\)); [1]

\[
\text{energy saved} = 0.020 \times 4817 = 96.34 \text{ kJ}
\]
(iii) calculate the decrease in volume of CO₂(g) emitted into the atmosphere.

Assume that the conditions are the same as room temperature and pressure. [2]

\[ \text{Mol CO}_2 = 0.020 \times 7 = 0.14 \]

\[ \text{Vol CO}_2 = 0.140 \times 24000 = 3360 \text{ cm}^3 \]

Comments

They forgot to change the kg into g! This would lose the first mark, but the other marks would all be awarded consequentially

Question 6 (d)

(d) Compound X is an atmospheric pollutant emitted from fuel combustion of petrol and diesel vehicles. Compound X is a potent human carcinogen.

- Analysis of compound X showed the following percentage composition by mass: C, 88.89%; H, 11.1%.

- Mass spectrometry showed a molecular ion peak at \( m/z = 54 \).

- Compound X reacts with H₂ in the presence of a nickel catalyst in a 1 : 2 molar ratio.

Analyse and interpret this information to determine a possible structure for compound X.

Show all your working. [5]

\[ \text{C } 88.89/12 = 7.41 \]

\[ \text{H } 11.1/1 = 11.1 \]

empirical formula = \( C_7H_{11} \)

\( Rfm = 54, \ C_7H_{11} = ?????? \)

Comments

The answer started well, but the ratio was not reduced to simple numbers, so when it came to the rfm the candidate did not know where to go next. Presumably, they did not have time to revisit this question.
Question 7 (a)

7 But-1-ene is just one isomer with the molecular formula C$_4$H$_8$.

(a) Using C$_4$H$_8$ 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.

Structural isomers have the same molecular formula, but they have different structures.

Cis-trans isomers cannot rotate around a carbon-carbon double bond.

Comments

Structural isomerism is well answered, both the definition and the examples, including the unusual cyclobutane. Cis-trans is also mostly correct, omitting only the requirement that each of the carbons must be attached to two different groups.
(b) The chemical properties of but-1-ene are similar to those of ethene.

- Using this information, predict the organic products in, and the equations for, the reactions of but-1-ene with bromine, hydrogen bromide and steam.

- Draw a section of the polymer formed from but-2-ene by showing two repeat units.

- Discuss two ways in which chemists are trying to minimise the damage to the environment caused by the disposal of polymers.

\[
\begin{align*}
\text{CH}_2=\text{CHCH}_2\text{CH}_3 + \text{Br}_2 & \rightarrow \text{CH}_2\text{BrCHBrCH}_2\text{CH}_3 \text{ 1,2-dibromobutane} \\
\text{CH}_2=\text{CHCH}_2\text{CH}_3 + \text{HBr} & \rightarrow \text{CH}_3\text{CHBrCH}_2\text{CH}_3 \text{ 2-bromobutane} \\
\text{CH}_2=\text{CHCH}_2\text{CH}_3 + \text{H}_2\text{O} & \rightarrow \text{CH}_3\text{CHOHCH}_2\text{CH}_3 \text{ bromobutan-2-ol}
\end{align*}
\]

Plastics and polymers should be burned in power stations to make electricity. Here they can control the temperature to avoid making dioxins. They could also crack the polymers into smaller chains like petrol and use it in cars.

Comments

The equations are all correct, but there are only three!

The candidate has forgotten that asymmetrical alkenes give two possible products with asymmetrical reagents. The polymer structure is correct. The final response gives two good suggestions.

Overall Comments

Overall a medium level response