Candidate Style Answer

Chemistry A

Unit F322 Chains, Energy and Resources – Medium banded response

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

Contents

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.

Unit F322 Chains, Energy and Resources

Medium banded response

Question 1

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

alkane	**number of carbon atoms**	**molecular formula**	**boiling point /°C**
butane	4	C_4H_{10}	0
pentane	5	C_5H_{12}	36
hexane	6	C_6H_{14}	69
heptane	7	C_7H_{16}	99
octane	8	C_8H_{18}	
nonane	9	C_9H_{20}	152
decane	10	$C_{10}H_{22}$	175

(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]**

$C_{13}H_{28}$

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

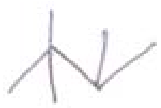
Write a balanced equation for the cracking of nonane into heptane and ethene. **[1]**

$C_9H_{20} \rightarrow C_7H_{16} + C_2H_4$

(d) Straight chain alkanes such as heptane, C_7H_{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]**



2,2,3-trimethylbutane

(ii) Write a balanced equation to show the formation of the cyclic compound methylcyclohexane from heptane. **[2]**

(e) Butane, C_4H_{10}, reacts with chlorine to produce a chloroalkane with molecular formula C_4H_9Cl.

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

(i) What is meant by the term *radical*? **[1]**

An atom with a single electron

(ii) State the conditions necessary to bring about the formation of the chlorine free radicals from Cl_2. **[1]**

UV

(iii) State the type of bond fission involved in the formation of the chlorine radicals. **[1]**

Heterolytic

(iv) The chlorine radicals react with butane in several steps to produce C_4H_9Cl.

Write equations for the two propagation steps. **[2]**

$$Cl. + C_4H_{10} \rightarrow C_4H_9. + HCl$$

$$C_4H_9. + Cl. \rightarrow C_4H_9Cl$$

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, $CH_3CH_2CH_2CH_2Br$, can be reacted with hot aqueous sodium hydroxide to prepare butan-1-ol.

$CH_3CH_2CH_2CH_2Br + OH^- \longrightarrow CH_3CH_2CH_2CH_2OH + Br^-$

(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 $CH_3CH_2CH_2CH_2Br$ reacted.

$CH_3CH_2CH_2CH_2Br$, M_r = 136.9 **[1]**

Moles = 8.72/123 = 0.0709 mol

(ii) Calculate the amount, in mol, of $CH_3CH_2CH_2CH_2OH$ produced. **[2]**

Moles = 4.28/74 = 0.0578 mol

(iii) Calculate the percentage yield.

Quote your answer to **three** significant figures. **[1]**

% = 0.0709/0.0637 x 100 = 111 %

Comments

The first part is incorrect: in fact there are two errors, the rfm has missed out one of the CH_2 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? **[1]**

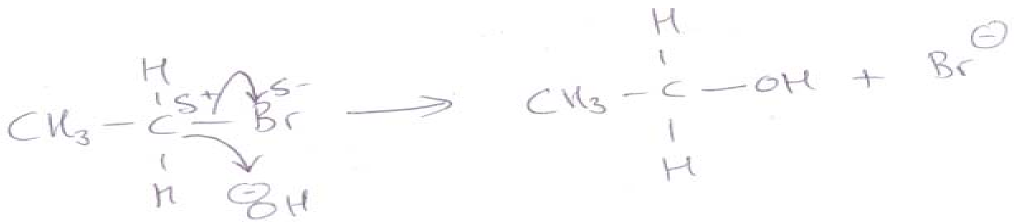
Substitution

(ii) Explain the term *nucleophile*. **[1]**

A nucleus lover

(iii) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles. **[4]**



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. **[2]**

$C_3H_7^+$ at 29 OH^- at 17

(ii) State a use of mass spectrometry outside of the laboratory. **[1]**

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, C_2H_5OH, 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, C_2H_5OH, is manufactured on a large scale by two methods:

- Fermentation, using yeast, of sugars, such as glucose, $C_6H_{12}O_6$.

  $C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

  The ethanol is then distilled off.

- Hydration of ethene, C_2H_4, with steam in the presence of an acid catalyst.

  $C_2H_4(g) + H_2O(g) \longrightarrow C_2H_5OH(g)$

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. **[7]**

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, CH_3CHO (**Fig. 3.1**), or ethanoic acid, CH_3COOH (**Fig. 3.2**).

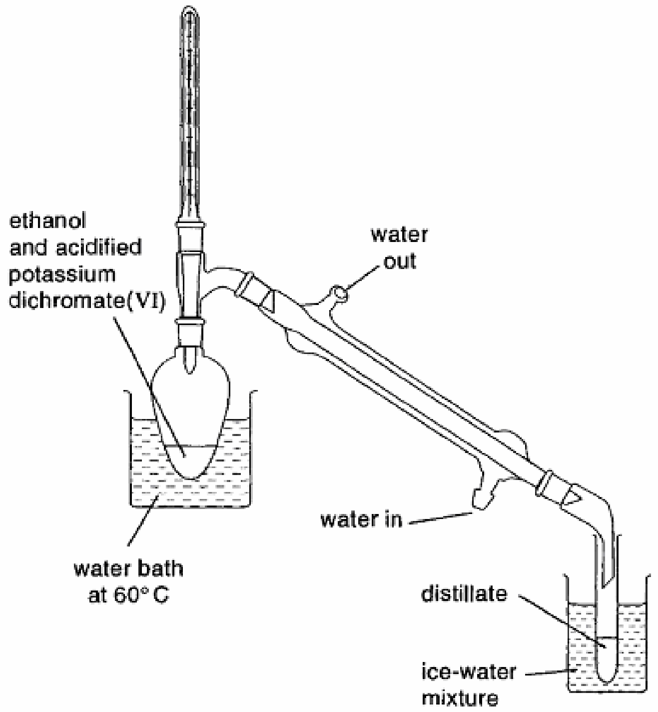


Fig. 3.1

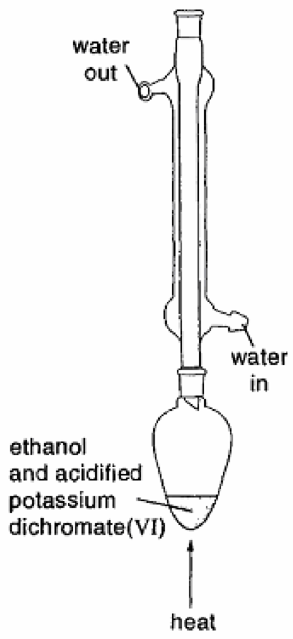


Fig. 3.2

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

	CH_3CH_2OH	CH_3CHO	CH_3COOH
boiling point / °C	78	21	118

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, **[2]**

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. **[2]**

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. **[2]**

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

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.

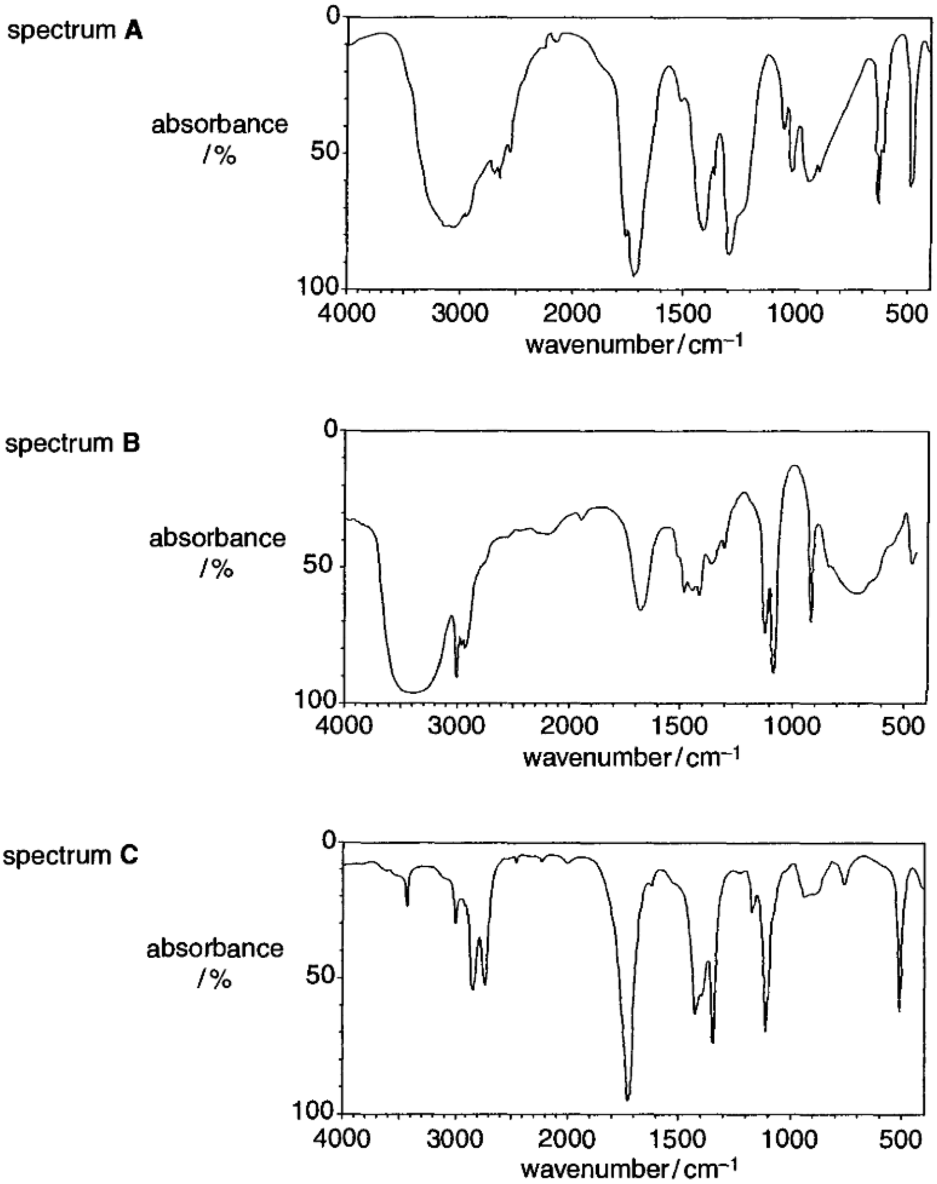


Fig 3.1 © SDBS, National Institute of Science and Technology, 2007

(b) The organic product collected when using the apparatus shown in **Fig. 3.1** is most likely to be that shown by spectrum …. **[2]**

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.

bond	**average bond enthalpy /kJ mol^{-1}**
C–H	+410
O–H	+465
O=O	+500
C=O	+805
C–O	+336

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

Breaking a bond is endothermic.

(ii) The equation below shows the combustion of methanol, CH_3OH, in the gaseous state.

$$CH_3OH(g) + 1\tfrac{1}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$

Using the average bond enthalpies in the table above, calculate the enthalpy change of combustion, ΔH_c, of gaseous methanol. **[3]**

Bond breaking = 3 x 410(C-H) + 336(C-O) + 465(O-H) + 1.5 x 500(O=O) = 2781 kJ

Bond making = -(2 x 805(C=O) + 2 x 465(O-H)) = -2540

Energy change = 2781 – 2540 = 241 kJ mol^{-1}

Comments

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.

$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$

The table below shows the standard enthalpy changes of formation for CH_4, H_2O and CO.

compound	$\Delta H_f^{\ominus}$**/kJ mol**$^{-1}$
CH_4	–75
H_2O	–242
CO	–110

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

The energy change when 1 mole of a substance is formed

(ii) In $\Delta H_f^{\ominus}$, what are the conditions indicated by the symbol $\ominus$? **[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]**

$2C(s) + O_2(g) \rightarrow 2CO(g)$

(iv) Using the $\Delta H_f^{\ominus}$ values in the table above, calculate the enthalpy change for the reaction of methane with steam.

$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$ **[3]**

Enthalpy change $= \Delta H_f^{\ominus}\ CO + 3\Delta H_f^{\ominus}\ H_2 - \Delta H_f^{\ominus}\ CH_4 - \Delta H_f^{\ominus}\ H_2O$

$= -110 + 3X0 - (-75) - (-242)$

$= +207\ kJ\ mol^{-1}$

Comments

(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. **[1]**

Hardening oils in margarine

Comments

Correct.

Question 5 (a)

5 Nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4, take part in the following equilibrium.

$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ mol}^{-1}$

(a) State le Chatelier's principle. **[2]**

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 NO_2/N_2O_4 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 NO_2.

(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]**

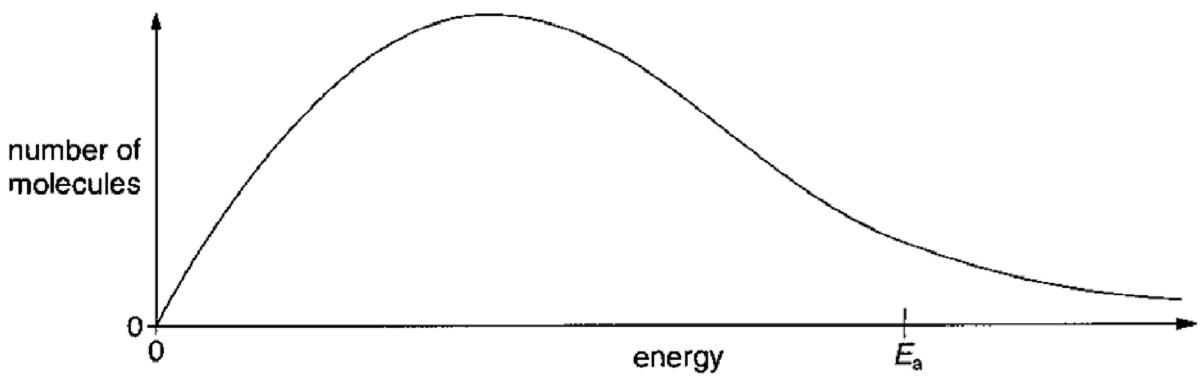
The equilibrium will not change.

Comments

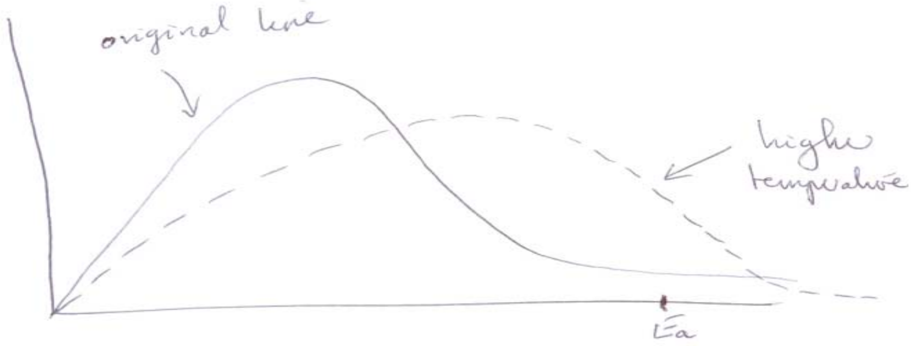
This candidate is struggling with equilibrium! The first answer covers the main points, but the second does not really say anything of value. The catalyst answer says no change, but nothing else.

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.



(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]**

$$Cl + O_3 \longrightarrow ClO + O_2$$

$$ClO + O \longrightarrow Cl + O_2$$

$$O_3 + O \rightarrow 2O_2$$

Comments

The equations are correct.

Question 6 (b)

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

(i) Heptane, C_7H_{16}, is a component in petrol.

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

$$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$$

(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_7H_{16}, saved; **[2]**

mol = 2/100 = 0.020 mol

(ii) calculate the energy saved (ΔH_c° [C_7H_{16}] = – 4817 kJ mol^{-1}); **[1]**

energy saved = 0.020 x 4817 = 96.34 kJ

(iii) calculate the decrease in volume of $CO_2(g)$ emitted into the atmosphere.

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

Mol CO_2 =0.020 x 7 = 0.14

Vol CO_2 = 0.140 x 24000 = 3360 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 H_2 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]**

C 88.89/12 = 7.41

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_4H_8.

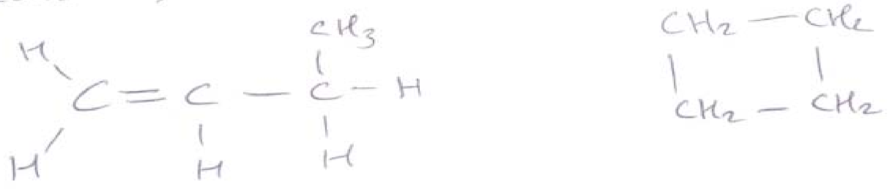
(a) Using C_4H_8 as your example, describe and explain what is meant by structural isomerism and *cis-trans* isomerism.

Include diagrams in your answer.

✎ In your answer you should make clear how each type of isomerism is related to structural features. **[7]**

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

Structural :-



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

Cis-trans :-

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.

Question 7 (b)

(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.

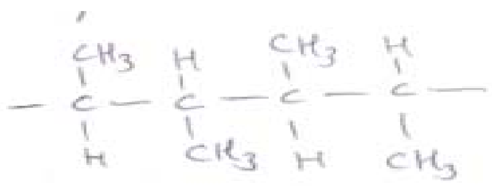
- Draw a section of the polymer formed from but-2-ene by showing two repeat units.

- Discuss **two** ways in which chemists are trying to minimise the damage to the environment caused by the disposal of polymers. **[10]**

$CH_2{=}CHCH_2CH_3 + Br_2 \rightarrow CH_2BrCHBrCH_2CH_3$ 1,2-dibromobutane

$CH_2{=}CHCH_2CH_3 + HBr \rightarrow CH_3CHBrCH_2CH_3$ 2-bromobutane

$CH_2{=}CHCH_2CH_3 + H_2O \rightarrow CH_3CHOHCH_2CH_3$ bromobutan-2-ol



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