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Candidate Style Answer

Chemistry A

Unit F322 Chains, Energy and Resources – High 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

High 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]**

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

As the carbon chain gets longer the boiling point gets higher. This is because there are more van der Waals forces between the molecules, so it takes more energy to separate them.

(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.

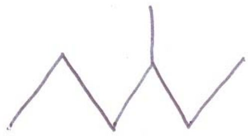
Write a balanced equation for the cracking of nonane into heptane and ethene. **[1]**

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

(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]**



3-methylhexane

(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 or group of atoms with an unpaired electron

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

UV light

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

Homolytic

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

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

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

$$C_4H_9. + Cl_2 \rightarrow C_4H_9Cl + Cl.$$

Comments

This is a very straightforward first question and high ability students would be expected to pick up most of the marks. This one has scored full marks, including a good explanation in part a(ii).

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 = 8.72/136.9 = 0.0637 mol

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

Moles = 4.28/73 = 0.0586 mol

(iii) Calculate the percentage yield.

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

% = 0.0586/0.0637 x 100 = 92.0 %

Comments

The first part is correct. However, the rfm in (ii) has been miscalculated. The candidate should have checked their working! 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]**

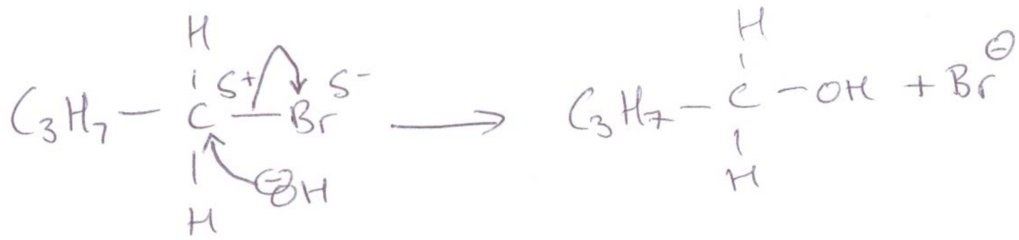
Nucleophilic substitution

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

An electron pair donor

(iii) Outline the mechanism for this reaction.

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



Comments

The first two parts are for simple recall. The mechanism is also straightforward, straight from the specification with only a longer carbon chain. The curly arrows and dipoles are carefully drawn, deserving full marks.

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]**

$C_3H_7^+$ $C_2H_5^+$

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

Breathalysers

Comments

Although both fragment ions are correct, there are no m/z values, therefore only one mark is given. "Breathalysers" is a correct answer for part (ii).

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]**

Making ethanol by fermentation is good for the environment. We can grow sugar cane every year so it will never run out.

Making ethanol from ethene is bad for the environment because ethene comes from crude oil which is non-renewable.

Both use energy. Fermentation is followed by distillation. Ethene needs fractional distillation and then cracking to make it.

In terms of atom economy using ethene is better as there are no other products.

Comments

From the mark scheme, the two marks for availability and the one mark for energy are clearly achieved. However, the candidate has not written enough about atom economy, as 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**).

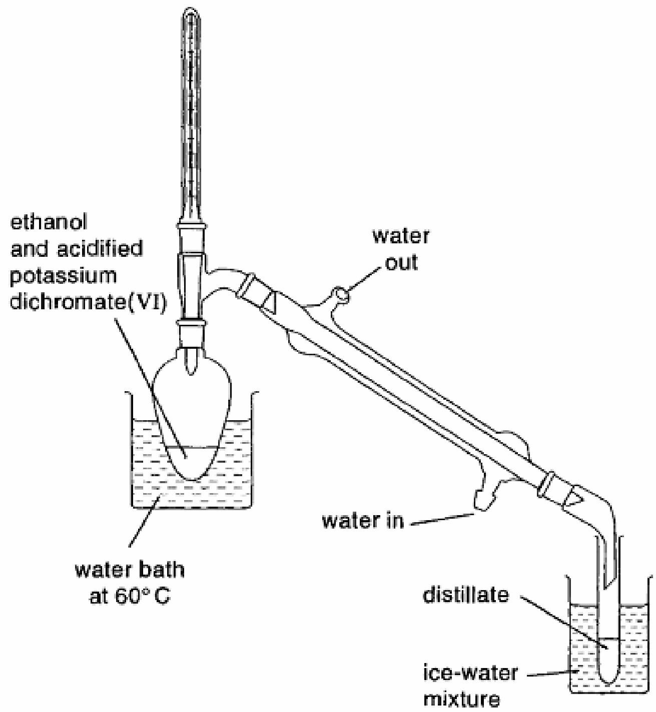


Fig. 3.1

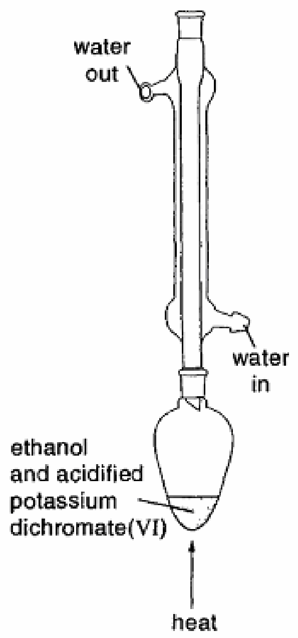


Fig. 3.2

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]**

It is distillation, the product is being distilled out as it is formed, so it will not be fully oxidised.

(ii) why the organic product is likely to be ethanoic acid if the apparatus shown in **Fig. 3.2** is used. **[2]**

It is under reflux, so the product cannot escape, it will be fully oxidised as long as it is heated for a long time.

Comments

The answer to the first part is incomplete as no reference is made to the boiling points. The second part is much better.

Question 3 (c)

(c) Write a balanced equation for the oxidation of ethanol to ethanoic acid. Use [O] to represent the oxidising agent. **[2]**

$$C_2H_5OH + 2[O] \rightarrow CH_3COOH$$

Comments

The organic molecules and the oxidising agent are correct, but they have forgotten water, the simpler product. This is quite a common error.

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.

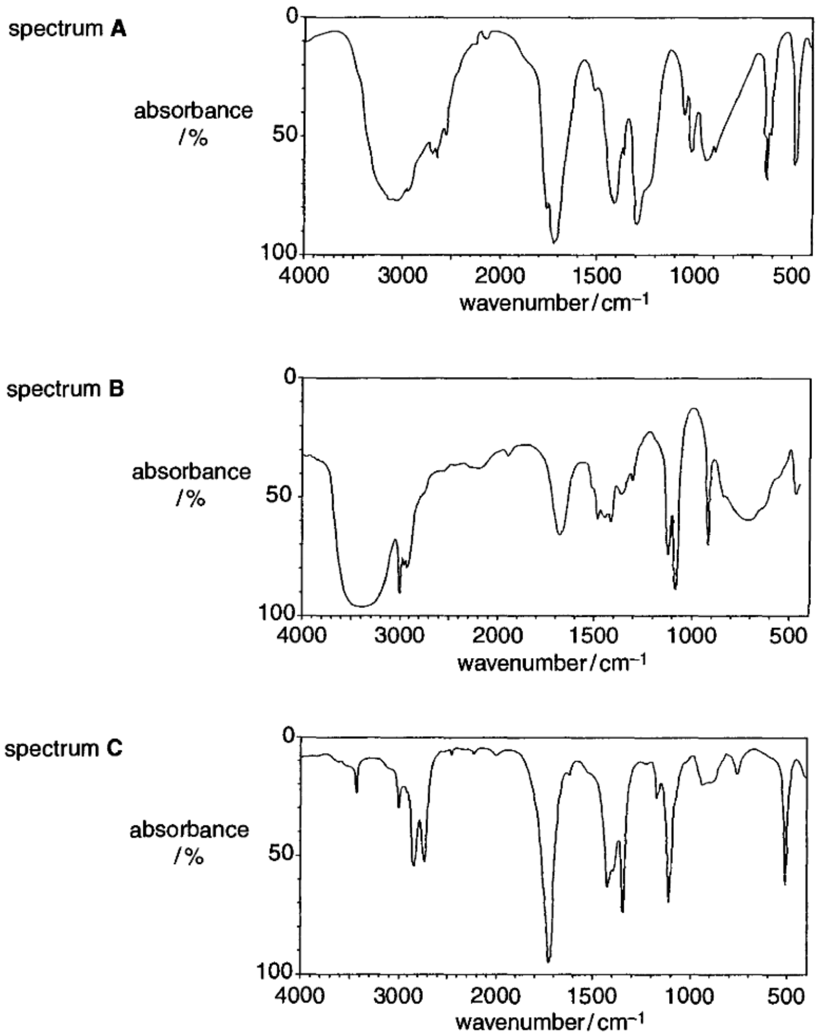


Fig 3.1 © SDBS, National Institute of Science and Technology, 2007

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 peak at 1650-1720 (C=O) which the others don't.

It does not have a peak at 2500-3200 (O-H) which the others do.

C must be the aldehyde.

Comments

A very good answer.

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]**

It takes in energy to break a bond.

(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 + 336 + 465 + 1.5 x 500 = 2781 kJ

Bond making = -(2 x 805 + 4 x 465) = -3470

Energy change = 2781 – 3470 = -689 kJ mol^{-1}

Comments

Although the definition is imprecise, it covers the main points. The calculation appears to be a jumble of numbers as no bonds are mentioned. In fact, they are all correct and give the correct answer, gaining full marks.

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 made from its elements.

(ii) In $\Delta H_f^{\ominus}$, what are the conditions indicated by the symbol $\ominus$? **[1]**

Standard conditions

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

$C(s) + 0.5O_2(g) \rightarrow CO(g)$

(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 = -110 –(-75) –(-242) = +207 kJ mol^{-1}

Comments

The definition is correct but the candidate has misunderstood the question in part (ii) and has not said what standard conditions are. The equation is correct, as is the calculation, but it once again lacks clarity.

Question 4 (c)

(c) State one important manufacturing process in which hydrogen is used. **[1]**

The Haber Process

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 Ie Chatelier's principle. **[2]**

When the conditions that affect a system in equilibrium are changed, then the equilibrium will shift in whatever direction attempts to restore the original conditions For example, if the temperature is increased then the equilibrium will move in the endothermic direction to lower the temperature.

Comments

Although the original definition is not totally clear, the use of a specific example ensures both marks. Good exam technique.

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.

(ii) The pressure is increased. **[2]**

The equilibrium will move to the right, where there are less gaseous molecules, lowering the pressure.

(iii) A catalyst is added. **[2]**

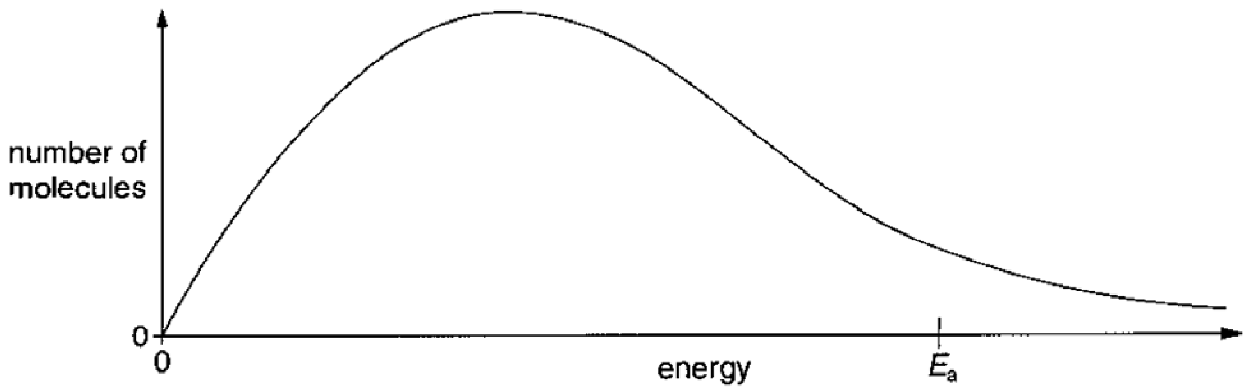
The equilibrium will not move as a catalyst does not affect the position of equilibrium.

Comments

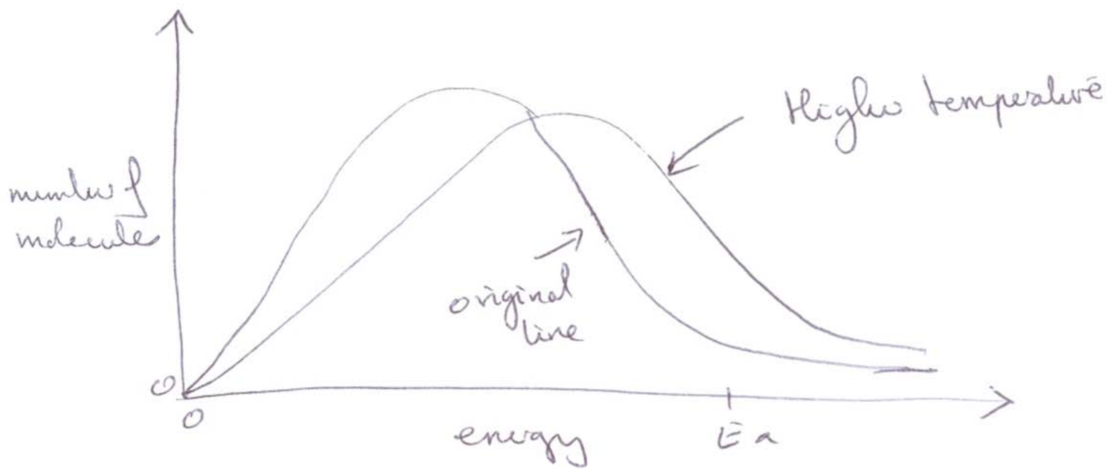
The first two answers explain the predicted equilibrium shift and therefore get marks. The catalyst answer effectively says no change twice, with no explanation, therefore missing the second marking point.

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]**

More molecules have the activation energy or greater.

Comments

The second curve gets the marks as the peak is lower and the curve is displaced to the right. However, the second answer does not really refer to the curves.

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 dioxide from 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]**

$$C_7H_{16} + 15O_2 \rightarrow 7CO_2 + 8H_2O$$

(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.

Comments

The equation is correct but the balancing is not. There is no mention of how the CO_2 absorbs IR radiation, ie no mention of the bonds vibrating.

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 = 2000/100 = 20 mol

(ii) calculate the energy saved ($\Delta H_c^{\ominus}$ [C_7H_{16}] = – 4817 kJ mol^{-1}); **[1]**

energy saved = 20 x 4817 = 96 340 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 = 20 x 7 = 140

Vol CO_2 = 140 x 24 = 3360 dm^3

Comments

All answers are correct.

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

Ratio C:H =7.41:11.1 = 2:3 *empirical formula = C_2H_3*

Rfm = 54, C_2H_3 = 27, therefore molecular formula = C_4H_6

$C_4H_6 + 2H_2 \rightarrow C_4H_{10}$ therefore 2 double bonds

Possible structure is CH_2=CH-CH=CH_2

Comments

An excellent answer. All the information is used and all the conclusions are correct.

Question 7 (a)

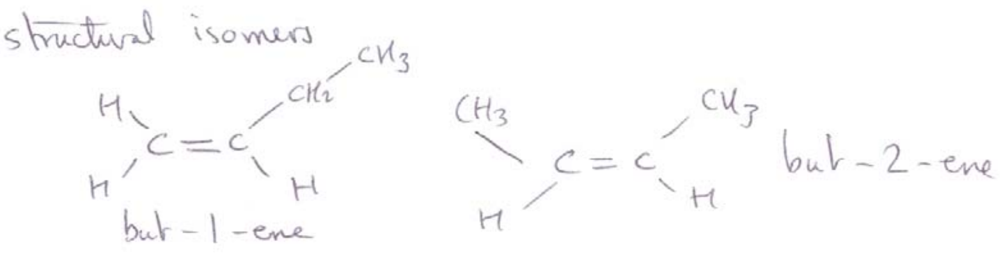
7 But-1-ene is just one isomer with the molecular formula C_4H_8.

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

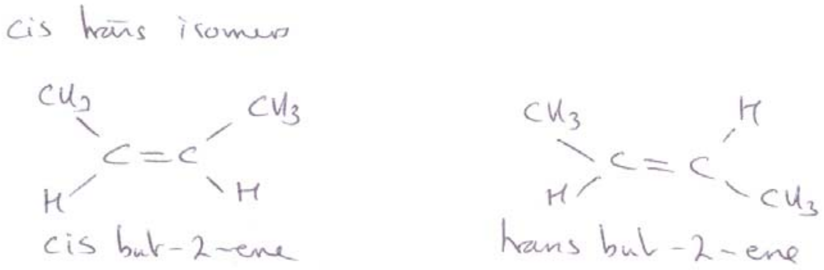
Include diagrams in your answer.

✎ 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 structural formulae.



Cis-trans isomers differ in the way the atoms are arranged in space, because rotation around a carbon-carbon double bond is very difficult. Each of the double bond carbons must be bonded to two different groups.



Comments

A perfect answer to a relatively easy question.

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 → $CH_2BrCHBrCH_2CH_3$ 1,2-dibromobutane

CH_2=$CHCH_2CH_3$ + HBr → $CH_3CHBrCH_2CH_3$ 2-bromobutane

And CH_2=$CHCH_2CH_3$ + HBr → $CH_2BrCH_2CH_2CH_3$ 1-bromobutane

CH_2=$CHCH_2CH_3$ + H_2O → $CH_3CHOHCH_2CH_3$ bromobutan-2-ol

And CH_2=$CHCH_2CH_3$ + H_2O → $CH_2OHCH_2CH_2CH_3$ bromobutan-1-ol

-$CHCH_3$-$CHCH_3$-$CHCH_3$-$CHCH_3$-

Polymers are non-biodegradable and fill landfill sites. They also give off toxic fumes when they burn.

We should recycle them wherever possible and use them as fuels in power stations.

Comments

The equations are all correct. The candidate has done well to remember that asymmetrical alkenes give two possible products with asymmetrical reagents. The polymer is not so good. They have attempted the backbone correctly, but a structural drawing would have made the answer clearer. Note that the published mark scheme incorrectly shows poly (but-1-ene). The final response gains no credit for recycling, as the question asks about disposal and that is not the same as recycling. The other suggestion is fine.

Overall Comments

Overall a very good candidate.