

Topic 10/20 Practice written questions organic chemistry [73 marks]

This question is about carbon and chlorine compounds.

- 1a. Ethane, C_2H_6 , reacts with chlorine in sunlight. State the type of this reaction and the name of the mechanism by which it occurs. [1 mark]

Type of reaction:

.....

Mechanism:

.....

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

Markscheme

substitution **AND** «free-»radical

OR

substitution **AND** chain

Award [1] for "«free-»radical substitution" or "S_R" written anywhere in the answer.

[1 mark]

Examiners report

[N/A]

- 1b. Formulate equations for the two propagation steps and one termination step in the formation of chloroethane from ethane.

[3 marks]

Two propagation steps:

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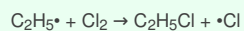
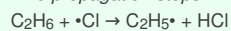
One termination step:

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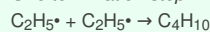
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Markscheme

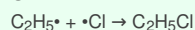
Two propagation steps:



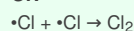
One termination step:



OR



OR



Accept radical without \cdot if consistent throughout.

Allow ECF from incorrect radicals produced in propagation step for M3.

[3 marks]

Examiners report

[N/A]

- 1c. One possible product, X, of the reaction of ethane with chlorine has the following composition by mass: [2 marks]

carbon: 24.27%, hydrogen: 4.08%, chlorine: 71.65%

Determine the empirical formula of the product.

.....

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Markscheme

$$\text{C} = \frac{24.27}{12.01} = 2.021 \text{ AND } \text{H} = \frac{4.08}{1.01} = 4.04 \text{ AND } \text{Cl} = \frac{71.65}{35.45} = 2.021$$

«hence» CH₂Cl

Accept

$$\begin{array}{r} \frac{24.27}{12.01} \\ \frac{4.08}{1.01} \\ \frac{71.65}{35.45} \end{array}$$

Do not accept C₂H₄Cl₂.

Award [2] for correct final answer.

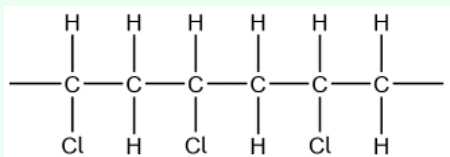
[2 marks]

Examiners report

[N/A]

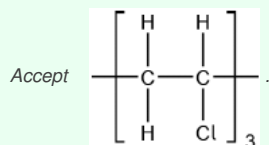
- 1d. Chloroethene, C₂H₃Cl, can undergo polymerization. Draw a section of the polymer with three repeating units. [1 mark]

Markscheme



Continuation bonds must be shown.

Ignore square brackets and "n".



Accept other versions of the polymer, such as head to head and head to tail.

Accept condensed structure provided all C to C bonds are shown (as single).

[1 mark]

Examiners report

[N/A]

Benzene is an aromatic hydrocarbon.

2a. Discuss the physical evidence for the structure of benzene.

[2 marks]

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Markscheme

Any two of:

planar «X-ray»

C to C bond lengths all equal

OR

C to C bonds intermediate in length between C–C and C=C

all C–C–C bond angles equal

Accept all C to C bonds have same bond strength/bond energy.

[2 marks]

Examiners report

[N/A]

- 2b. State the typical reactions that benzene and cyclohexene undergo with bromine.

[1 mark]

Benzene:

.....

Cyclohexene:

.....

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.....

Markscheme

benzene: «electrophilic» substitution/S_E

AND

cyclohexene: «electrophilic» addition/A_E

Accept correct equations.

[1 mark]

Examiners report

[N/A]

The photochemical chlorination of methane can occur at low temperature.

- 3a. Using relevant equations, show the initiation and the propagation steps for this reaction.

[3 marks]

Initiation:

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Propagation:

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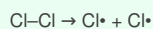
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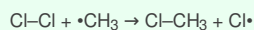
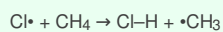
.....

Markscheme

Initiation:



Propagation:



Do not penalize missing electron dot on radicals if consistent throughout.

Accept Cl_2 , HCl and CH_3Cl without showing bonds.

*Do **not** accept hydrogen radical, $\text{H}\cdot$ or H , but apply ECF to other propagation steps.*

[3 marks]

Examiners report

[N/A]

- 3b. Bromine was added to hexane, hex-1-ene and benzene. Identify the compound(s) which will react with bromine in a well-lit laboratory.

[1 mark]

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.....

Markscheme

hexane **AND** hex-1-ene

*Accept "benzene **AND** hexane **AND** hex-1-ene".*

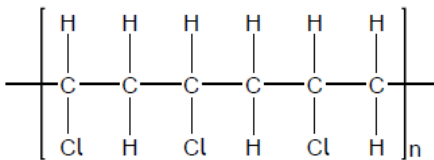
[1 mark]

Examiners report

[N/A]

3c. Polyvinyl chloride (PVC) is a polymer with the following structure.

[1 mark]



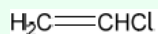
State the structural formula for the monomer of PVC.

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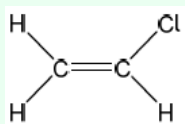
.....

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Markscheme



OR



Accept " CH_2CHCl " or " CHClCH_2 ".

Do **not** accept " $\text{C}_2\text{H}_3\text{Cl}$ ".

[1 mark]

Examiners report

[N/A]

This question is about carbon and chlorine compounds.

4a. Ethane, C_2H_6 , reacts with chlorine in sunlight. State the type of this reaction and the name of the mechanism by which it occurs.

[1 mark]

Type of reaction:

.....

Mechanism:

.....

.....

.....

.....

Markscheme

substitution **AND** «free-»radical

OR

substitution **AND** chain

Award [1] for “«free-»radical substitution” or “S_R” written anywhere in the answer.

[1 mark]

Examiners report

[N/A]

- 4b. Formulate equations for the two propagation steps and one termination step in the formation of chloroethane from ethane.

[3 marks]

Two propagation steps:

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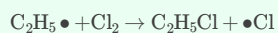
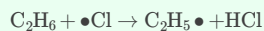
One termination step:

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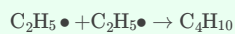
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Markscheme

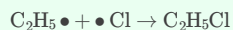
Two propagation steps:



One termination step:



OR



OR



Accept radical without \bullet if consistent throughout.

Allow ECF for incorrect radicals produced in propagation step for M3.

[3 marks]

Examiners report

[N/A]

- 4c. Deduce the splitting patterns in the ^1H NMR spectrum of $\text{C}_2\text{H}_5\text{Cl}$.

[1 mark]

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.....

Markscheme

triplet **AND** quartet

[1 mark]

Examiners report

[N/A]

4d. Explain why tetramethylsilane (TMS) is often used as a reference standard in ^1H NMR.

[2 marks]

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Markscheme

chemical shift/signal outside range of common chemical shift/signal

strong signal/12/all H atoms in same environment

OR

singlet/no splitting of the signal

volatile/easily separated/easily removed

OR

inert/stable

contains three common NMR nuclei/ ^1H and ^{13}C and ^{29}Si

*Do **not** accept chemical shift = 0.*

[2 marks]

Examiners report

[N/A]

4e. One possible product, **X**, of the reaction of ethane with chlorine has the following composition by mass:

[2 marks]

carbon: 24.27%, hydrogen: 4.08%, chlorine: 71.65%

Determine the empirical formula of the product.

.....

.....

.....

.....

.....

.....

Markscheme

$$\text{C} = \frac{24.27}{12.01} = 2.021 \text{ *AND* } \text{H} = \frac{4.08}{1.01} = 4.04 \text{ *AND* } \text{Cl} = \frac{71.65}{35.45} = 2.021$$

«hence» CH_2Cl

Accept

$$\frac{24.27}{12.01} :$$

$$\frac{4.08}{1.01} :$$

$$\frac{71.65}{35.45} :$$

*Do **not** accept $\text{C}_2\text{H}_4\text{Cl}_2$.*

Award [2] for correct final answer.

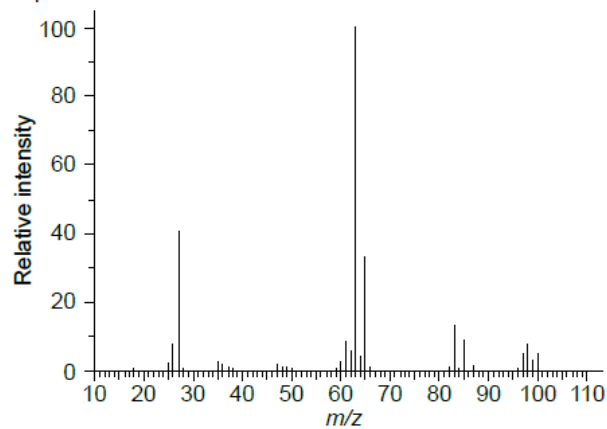
[2 marks]

Examiners report

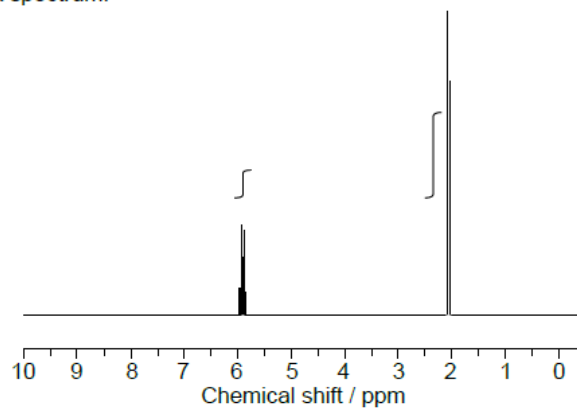
[N/A]

- 4f. The mass and ^1H NMR spectra of product **X** are shown below. Deduce, giving your reasons, its structural formula and hence the name of the compound. [3 marks]

Mass spectrum:



^1H NMR spectrum:



[Source: <http://sdfs.db.aist.go.jp>]

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Markscheme

molecular ion peak(s) «about» m/z 100 **AND** «so» $C_2H_4Cl_2$ «isotopes of Cl»

two signals «in 1H NMR spectrum» **AND** «so» CH_3CHCl_2

OR

«signals in» 3:1 ratio «in 1H NMR spectrum» **AND** «so» CH_3CHCl_2

OR

one doublet and one quartet «in 1H NMR spectrum» **AND** «so» CH_3CHCl_2

1,1-dichloroethane

Accept "peaks" for "signals".

Allow ECF for a correct name for M3 if an incorrect chlorohydrocarbon is identified.

[3 marks]

Examiners report

[N/A]

- 4g. When the product **X** is reacted with NaOH in a hot alcoholic solution, C_2H_3Cl is formed. State the role of the reactant NaOH other than as a nucleophile. [1 mark]

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.....
.....

Markscheme

base

OR

proton acceptor

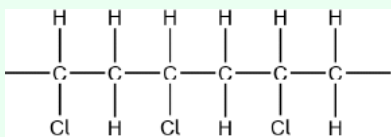
[1 mark]

Examiners report

[N/A]

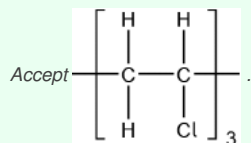
- 4h. Chloroethene, C_2H_3Cl , can undergo polymerization. Draw a section of the polymer with three repeating units. [1 mark]

Markscheme



Continuation bonds must be shown.

Ignore square brackets and "n".



Accept other versions of the polymer, such as head to head and head to tail.

Accept condensed structure provided all C to C bonds are shown (as single).

[1 mark]

Examiners report

[N/A]

An acidic sample of a waste solution containing $\text{Sn}^{2+}(\text{aq})$ reacted completely with $\text{K}_2\text{Cr}_2\text{O}_7$ solution to form $\text{Sn}^{4+}(\text{aq})$.

- 5a. Identify one organic functional group that can react with acidified $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$.

[1 mark]

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.....
.....

Markscheme

hydroxyl/OH
OR
aldehyde/CHO

Accept "hydroxy/alcohol" for "hydroxyl".

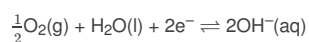
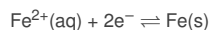
Accept amino/amine/ NH_2 .

[1 mark]

Examiners report

[N/A]

- 5b. Corrosion of iron is similar to the processes that occur in a voltaic cell. The initial steps involve the following half-equations: [1 mark]



Calculate E^{\ominus} , in V, for the spontaneous reaction using section 24 of the data booklet.

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.....
.....

Markscheme

« E^{\ominus} =» +0.85 «V»

Accept 0.85 V.

[1 mark]

Examiners report

[N/A]

- 5c. Calculate the Gibbs free energy, ΔG^{\ominus} , in kJ, which is released by the corrosion of 1 mole of iron. Use section 1 of the data booklet. [2 marks]

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.....
.....

Markscheme

ΔG^{\ominus} «= $-nFE^{\ominus}$ » = -2 «mol e^{-} » x 96500 «C mol $^{-1}$ » x 0.85 «V»

« ΔG^{\ominus} =» -164 «kJ»

Accept "«+»164 «kJ»" as question states energy released.

Award [1 max] for "+" or "-" 82 «kJ».

Do not accept answer in J.

[2 marks]

Examiners report

[N/A]

5d. Explain why iron forms many different coloured complex ions.

[3 marks]

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Markscheme

incompletely filled d-orbitals

colour depends upon the energy difference between the split d-orbitals

variable/multiple/different oxidation states

different «nature/identity of» ligands

different number of ligands

[3 marks]

Examiners report

[N/A]

5e. Zinc is used to galvanize iron pipes, forming a protective coating. Outline how this process prevents corrosion of the iron pipes.

[1 mark]

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.....

.....

Markscheme

Zn/zinc is a stronger reducing agent than Fe/iron

OR

Zn/zinc is oxidized instead of Fe/iron

OR

Zn/zinc is the sacrificial anode

Accept "Zn is more reactive than Fe".

Accept "Zn oxide layer limits further corrosion".

Do not accept "Zn layer limits further corrosion".

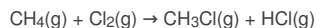
[1 mark]

Examiners report

[N/A]

6. The overall equation for monochlorination of methane is:

[2 marks]



Calculate the standard enthalpy change for the reaction, ΔH^\ominus , using section 12 of the data booklet.

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Markscheme

« ΔH^\ominus =» -82.0 «kJ» -92.3 «kJ» - (-74.0 «kJ»)

« ΔH^\ominus =» -100.3 «kJ»

Award [2] for correct final answer.

[2 marks]

Examiners report

[N/A]

- 7a. Bromine was added to hexane, hex-1-ene and benzene. Identify the compound(s) which will react with bromine in a well-lit laboratory.

[1 mark]

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.....

.....

Markscheme

hexane **AND** hex-1-ene

Accept "benzene **AND** hexane **AND** hex-1-ene".

[1 mark]

Examiners report

[N/A]

7b. Deduce the structural formula of the main organic product when hex-1-ene reacts with hydrogen bromide.

[1 mark]

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.....

Markscheme

CH3CH2CH2CH2CHBrCH3

Accept displayed formula but **not** molecular formula.

[1 mark]

Examiners report

[N/A]

7c. State the reagents and the name of the mechanism for the nitration of benzene.

[2 marks]

Reagents:
.....

Name of mechanism:
.....

.....

.....

.....

Markscheme

Reagents: «concentrated» sulfuric acid **AND** «concentrated» nitric acid

Name of mechanism: electrophilic substitution

[2 marks]

Examiners report

[N/A]

- 7d. Outline, in terms of the bonding present, why the reaction conditions of halogenation are different for alkanes and benzene. [1 mark]

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.....
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Markscheme

benzene has «delocalized» π bonds «that are susceptible to electrophile attack» **AND** alkanes do not

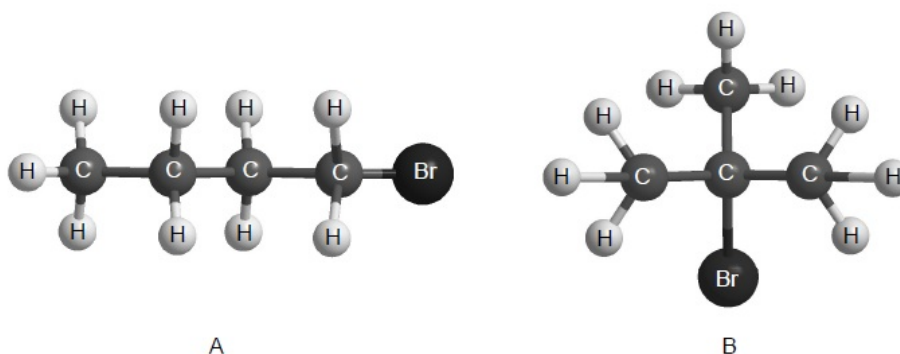
Do **not** accept "benzene has single and double bonds".

[1 mark]

Examiners report

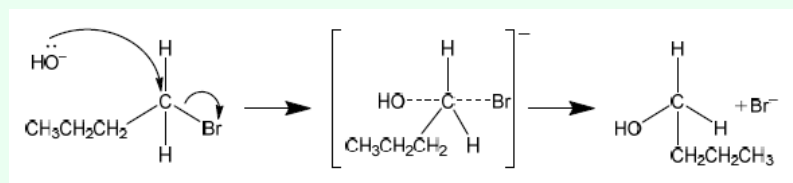
[N/A]

- 7e. Below are two isomers, A and B, with the molecular formula C_4H_9Br . [3 marks]



Explain the mechanism of the nucleophilic substitution reaction with $NaOH(aq)$ for the isomer that reacts almost exclusively by an S_N2 mechanism using curly arrows to represent the movement of electron pairs.

Markscheme



curly arrow going from lone pair/negative charge on O in OH^- to C

curly arrow showing Br leaving

representation of transition state showing negative charge, square brackets and partial bonds

Accept OH^- with or without the lone pair.

Do not allow curly arrows originating on H in OH^- .

Accept curly arrows in the transition state.

Do not penalize if HO and Br are not at 180° .

Do not award M3 if OH–C bond is represented.

Award **[2 max]** if wrong isomer is used.

[3 marks]

Examiners report

[N/A]

The Bombardier beetle sprays a mixture of hydroquinone and hydrogen peroxide to fight off predators. The reaction equation to produce the spray can be written as:



- 8a. Hydrogenation of propene produces propane. Calculate the standard entropy change, ΔS^\ominus , for the hydrogenation of propene. [2 marks]

Formula	$S^\ominus / \text{JK}^{-1}\text{mol}^{-1}$
$\text{H}_2(\text{g})$	+131
$\text{C}_3\text{H}_6(\text{g})$	+267
$\text{C}_3\text{H}_8(\text{g})$	+270

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.....

.....

Markscheme

« ΔS^\ominus =» 270 «J K⁻¹ mol⁻¹» – 267 «J K⁻¹ mol⁻¹» – 131 «J K⁻¹ mol⁻¹»

« ΔS^\ominus =» –128 «J K⁻¹ mol⁻¹»

Award [2] for correct final answer.

[2 marks]

Examiners report

[N/A]

- 8b. The standard enthalpy change, ΔH^\ominus , for the hydrogenation of propene is –124.4 kJ mol⁻¹. Predict the temperature above which the hydrogenation reaction is not spontaneous. *[2 marks]*

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Markscheme

«non spontaneous if» $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus > 0$

OR

$\Delta H^\ominus > T\Delta S^\ominus$

« T above» $\frac{-124.4 \text{ «kJ mol}^{-1}\text{»}}{-0.128 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»}} = 972 \text{ «K»}$

Award [2] for correct final answer.

Accept 699 °C.

Do not award M2 for any negative T value.

[2 marks]

Examiners report

[N/A]

Infrared (IR) spectroscopy is often used for the identification of polymers, such as PETE, for recycling.

LDPE and high density polyethene (HDPE) have very similar IR spectra even though they have rather different structures and physical properties.

9. Explain why the difference in their structures affects their melting points.

[2 marks]

Markscheme

HDPE «polymer» chains/molecules can pack together more closely «than LDPE chains»

OR

HDPE «polymer» chains/molecules have a higher contact surface area «than LDPE chains»

stronger intermolecular/dispersion/London/van der Waals' forces in HDPE **AND** higher melting point

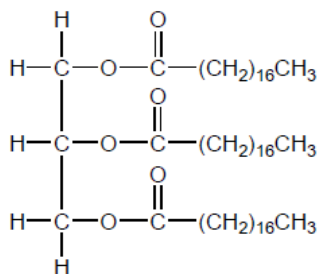
Accept converse arguments.

[2 marks]

Examiners report

[N/A]

Vegetable oils, such as that shown, require conversion to biodiesel for use in current internal combustion engines.



- 10a. State **two** reagents required to convert vegetable oil to biodiesel.

[2 marks]

Markscheme

methanol

OR

ethanol

strong acid

OR

strong base

Accept "alcohol".

Accept any specific strong acid or strong base other than HNO_3 /nitric acid.

[3 marks]

Examiners report

[N/A]

- 10b. Deduce the formula of the biodiesel formed when the vegetable oil shown is reacted with the reagents in (a).

[1 mark]

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.....
.....

Markscheme

$\text{CH}_3(\text{CH}_2)_{16}\text{COOCH}_3$ / $\text{CH}_3\text{OCO}(\text{CH}_2)_{16}\text{CH}_3$

OR

$\text{CH}_3(\text{CH}_2)_{16}\text{COOC}_2\text{H}_5$ / $\text{C}_2\text{H}_5\text{OCO}(\text{CH}_2)_{16}\text{CH}_3$

Product **must** correspond to alcohol chosen in (a), but award mark for either structure if neither given for (a).

[1 mark]

Examiners report

[N/A]

- 10c. Explain, in terms of the molecular structure, the critical difference in properties that makes biodiesel a more suitable liquid fuel than [2 marks]
vegetable oil.

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.....

Markscheme

lower viscosity

weaker intermolecular/dispersion/London/van der Waals' forces

OR

smaller/shorter molecules

Accept "lower molecular mass/ M_r " or "lower number of electrons".

Accept converse arguments.

[2 marks]

Examiners report

[N/A]

- 10d. Determine the specific energy, in kJ g^{-1} , and energy density, in kJ cm^{-3} , of a particular biodiesel using the following data and section 1 of the data booklet. [2 marks]

Density = 0.850 g cm^{-3} ; Molar mass = 299 g mol^{-1} ;

Enthalpy of combustion = 12.0 MJ mol^{-1} .

Specific energy:

.....
.....

Energy density:

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Markscheme

Specific energy: «= $\frac{12\,000 \text{ kJ mol}^{-1}}{299 \text{ g mol}^{-1}}$ » = 40.1 « kJ g^{-1} »

Energy density: «= $40.1 \text{ kJ g}^{-1} \times 0.850 \text{ g cm}^{-3}$ » = 34.1 « kJ cm^{-3} »

Award [1] if both are in terms of a unit other than kJ (such as J or MJ).

[2 marks]

Examiners report

[N/A]

11. Vision is dependent on retinol (vitamin A) present in retina cells. Retinol is oxidized to the photosensitive chemical 11- *cis*-retinal [2 marks] and isomerizes to 11-*trans*-retinal on absorption of light.

Outline how the formation of 11-*trans*-retinal results in the generation of nerve signals to the brain.

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Markscheme

11-*trans* retinal no longer fits into the rhodopsin/protein

OR

11-*trans* retinal is ejected from the rhodopsin/protein

leads to conformational change in rhodopsin/protein «to opsin generating signals»

[2 marks]

Examiners report

[N/A]

A polarimeter can be used to determine the optical rotation of an optically active substance.

- 12a. Describe what happens to plane-polarized light when it passes through a solution of an optically active compound. [1 mark]

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.....

.....

Markscheme

plane of polarization is rotated

Award zero if answer refers to plane-polarized light being bent.

[1 mark]

Examiners report

[N/A]

- 12b. A mixture of enantiomers shows optical rotation.
Suggest a conclusion you can draw from this data.

[1 mark]

Markscheme

not a racemic mixture

OR

two enantiomers not equimolar

OR

mixture contains optically active impurity

OR

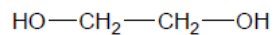
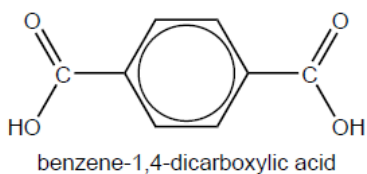
relative proportions of enantiomers in mixture can be determined

[1 mark]

Examiners report

[N/A]

Antimony oxide is widely used as a homogeneous catalyst for the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol in the production of polyethylene terephthalate (PETE).



ethane-1,2-diol

13a. Deduce the repeating unit of the polymer and the other product of the reaction.

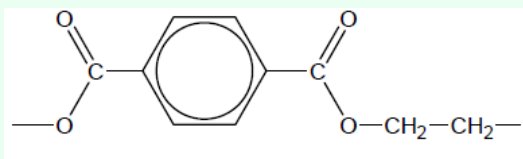
[2 marks]

Repeating unit:

Other product:

Markscheme

Repeating unit:



Other product: water/H₂O

Continuation bonds necessary for the mark.

Accept alternative repeating unit with O at other end.

Do not penalize square brackets or n.

[2 marks]

Examiners report

[N/A]

13b. State the class of polymer to which PETE belongs.

[1 mark]

.....

.....

.....

Markscheme

condensation

Accept polyester or thermoplastic.

[1 mark]

Examiners report

[N/A]

Ethanol is a depressant that is widely consumed in many societies. When consumed excessively it has a major impact on families and society as a whole. Other depressants such as diazepam (Valium®) may be prescribed by a doctor.

One problem associated with ethanol consumption is an increased risk of traffic accidents. Police in many countries use a breathalyser to test drivers. The breathalyser contains potassium dichromate(VI).

14a. Describe the colour change of potassium dichromate(VI) when it reacts with ethanol.

[1 mark]

.....

.....

.....

Markscheme

orange to green;

Examiners report

[N/A]

14b. State with a reason whether chromium in potassium dichromate(VI) is oxidised or reduced by ethanol.

[1 mark]

.....

.....

.....

Markscheme

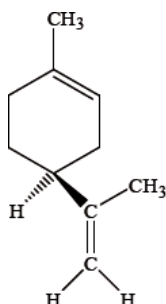
reduced because oxidation number of Cr decreases / Cr gains electrons;

Explanation needed for mark.

Examiners report

Candidates frequently confused oxidation and reduction or failed to provide a reason as to whether the chromium was oxidised or reduced by ethanol. This highlighted, again, the need for candidates to answer all parts of the question.

Different conventions are used to classify enantiomers. Orange and lemon peel each contain different enantiomers of the compound limonene. One of the enantiomers is represented below.



15a. Identify the chiral centre in this enantiomer with an asterisk, *.

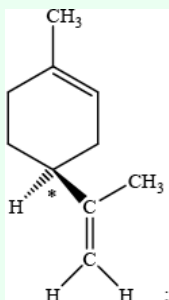
[1 mark]

.....

.....

.....

Markscheme



Examiners report

In (a), surprisingly a number of students were not able to identify the chiral centre.

- 15b. The (+)*d*-enantiomer has the characteristic smell of oranges and the (–)*l*-enantiomer has the characteristic smell of lemons. [1 mark]
Explain the meaning of the (+)*d* and (–)*l* symbols used in this notation.

.....

.....

.....

Markscheme

dextro/*d* and levo/*l* refer to right and left-handed / clockwise and anti-clockwise rotation of plane polarized light;

Examiners report

Although some knew what *d* and *l* referred to, a number did not refer to plane-polarized light.

- 15c. The R, S notation is also used. The (+)*d*-enantiomer is often described as R-limonene and the (–)*l*-enantiomer as S-limonene. [2 marks]
Explain what is meant by the R, S notation and state whether the structure shown is R or S.

.....

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Markscheme

clockwise and anti-clockwise sequence of prioritized atoms (working from high to low atomic numbers) / *OWTTE*;

Allow absolute configuration of enantiomers.

Allow convention for labelling chiral carbon atoms using the Cahn-Ingold-Prelog notation.

S;

Examiners report

R and S notation was not understood and only the best candidates were able to determine the structure as S. Some simple class exercises on chiral centres, *d* and *l* notation and R and S notation using a number of simple molecules would greatly improve student understanding of this topic.