

Organic chemistry

Mark scheme and worked solutions for 30 questions: 15 multiple choice, 15 structured.

1 Core Formulae, functional groups and terminology [1]

Answer: D

Worked solution

Substitute the number of carbon atoms into each general formula. For $n = 5$, C_nH_{2n+2} gives C_5H_{12} . Option A has two hydrogen atoms fewer than this, which is the pattern for alkenes (C_nH_{2n}). Options B and C contain oxygen, so they cannot be members of a series whose general formula contains only C and H; they are an alcohol and a carboxylic acid.

2 Core Formulae, functional groups and terminology [1]

Answer: C

Worked solution

"Unsaturated" means that one or more **carbon-carbon** bonds are not single bonds. Look only at the bonds between carbon atoms. In propene, $CH_2=CHCH_3$, the "=" is between two carbon atoms, so propene is unsaturated. A common mistake is to choose ethanoic acid, CH_3COOH , because it contains a double bond. That double bond is between carbon and oxygen ($C=O$), not between two carbon atoms, so it does not make the compound unsaturated.

3 Supplement Formulae, functional groups and terminology [1]

Answer: A

Worked solution

Structural isomers need the **same molecular formula** but a **different structural formula**. Count atoms in each pair first. In A, both compounds contain 5 C and 12 H, and one has a branch (a CH_3 group on the second carbon) while the other is a straight chain, so they are isomers. In B, $CH_3CH_2CH=CH_2$ read backwards is $CH_2=CHCH_2CH_3$: it is the same molecule, with the double bond at the end of the chain in both. In C the hydrogen counts differ (10 and 8). In D the compounds differ by a CH_2 unit, which makes them homologues, not isomers.

Mark scheme

(a) [2]

- a family of (similar) compounds with similar chemical properties (1)
- due to the presence of the same functional group (1)

ALLOW same general formula / differ by CH_2 for the first mark if "similar compounds" is also stated

REJECT "compounds with the same formula"

(b) [1]

- $-\text{OH}$ / hydroxyl (group) (1)

ALLOW OH

REJECT hydroxide / OH^- (ion)

(c) [1]

- C_5H_{10} (1)

(d) [1]

- $\text{C}_4\text{H}_9\text{OH}$ (1)

ALLOW $\text{C}_4\text{H}_{10}\text{O}$

Worked solution

(a) A homologous series is a family of similar compounds which have similar chemical properties because they all contain the same functional group.

(b) The functional group of the alcohols is $-\text{OH}$. It is covalently bonded to carbon, so do not call it a hydroxide ion.

(c) Alkenes have the general formula C_nH_{2n} . With $n = 5$, the number of hydrogen atoms is $2 \times 5 = 10$, giving C_5H_{10} .

(d) Alcohols have the general formula $\text{C}_n\text{H}_{2n+1}\text{OH}$. With $n = 4$, $2n + 1 = 9$, giving $\text{C}_4\text{H}_9\text{OH}$.

Mark scheme

(a) [1]

- boiling point increases as the number of carbon atoms / molecular size / chain length increases (1)

ALLOW increases down the table

REJECT "increases" with no reference to what it increases with, unless it is clear from context that it means going down the table

(b) [1]

- any value in the range 130–145 °C (1)

(c) [2]

Any two from:

- same functional group (1)
- same general formula (1)
- each member differs from the next by a $\text{-CH}_2\text{-}$ unit (1)
- similar chemical properties (1)

(d)(i) [1]

- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ (1)

ALLOW a correct displayed formula

REJECT $\text{C}_4\text{H}_9\text{OH}$

(d)(ii) [2]

- other compounds / isomers (e.g. butan-2-ol) have the same molecular formula, $\text{C}_4\text{H}_9\text{OH}$ (1)
- structural formula shows the (unambiguous) arrangement of the atoms / where the -OH group is attached (1)

ALLOW $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$ as an example of another compound with this molecular formula

Worked solution

(a) Reading down the table, each alcohol has one more carbon atom than the one before, and the boiling point rises each time. So boiling point increases as chain length increases.

(b) The rises are 13 °C, 19 °C and 20 °C. Adding roughly another 20 °C to 117 °C gives about 137 °C. Any sensible value between 130 °C and 145 °C is acceptable.

(c) Members of a homologous series have the same functional group, the same general formula, differ from one member to the next by $\text{-CH}_2\text{-}$ and have similar chemical properties. Any two of these score.

(d)(i) Butan-1-ol has an unbranched chain of four carbon atoms with the -OH on the first carbon:
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$.

(d)(ii) A molecular formula only tells you how many of each atom there are. Butan-2-ol, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$, also has the molecular formula $\text{C}_4\text{H}_9\text{OH}$. A structural formula is an unambiguous

description of how the atoms are arranged, so it shows which carbon the –OH group is on.

6 Supplement Formulae, functional groups and terminology [7]

Mark scheme

(a) [2]

- (compounds with) the same molecular formula (1)
- but different structural formulae (1)

ALLOW different arrangement of atoms for the second mark

REJECT "same formula, different structure" for the first mark unless "molecular" is stated or clearly implied

(b) [1]

- C_nH_{2n} with $n = 4$ gives $2 \times 4 = 8$ hydrogen atoms, so C_4H_8 (1)

(c) [2]

- $CH_2=CHCH_2CH_3$ (1)
- $CH_3CH=CHCH_3$ (1)

ALLOW $CH_3CH_2CH=CH_2$ for but-1-ene

ALLOW correct displayed formulae

REJECT branched structures such as $CH_2=C(CH_3)CH_3$ (not unbranched)

(d)(i) [1]

- 8 (1)

(d)(ii) [1]

- 2 (1)

Worked solution

(a) Structural isomers are compounds with the same molecular formula but different structural formulae.

(b) The alkene general formula is C_nH_{2n} . For four carbon atoms, the number of hydrogen atoms is $2 \times 4 = 8$, which matches C_4H_8 .

(c) With an unbranched chain of four carbon atoms, the C=C double bond can be between carbons 1 and 2 (but-1-ene, $CH_2=CHCH_2CH_3$) or between carbons 2 and 3 (but-2-ene, $CH_3CH=CHCH_3$). Putting the double bond between carbons 3 and 4 just gives but-1-ene again, written backwards.

(d) Picture the displayed formula of $CH_2=CH-CH_2-CH_3$. The hydrogen atoms are $2 + 1 + 2 + 3 = 8$, and each hydrogen atom has one bond to carbon, so there are 8 C–H bonds. Between the carbon atoms there is one C=C double bond (C1–C2) and two C–C single bonds (C2–C3 and C3–C4).

7

Core

Naming organic compounds

[1]

Answer: C**Worked solution**

Split the name into two parts. "Prop-" means three carbon atoms. "-ene" means the compound is an alkene, with a C=C double bond. Alkenes have the general formula C_nH_{2n} , so three carbon atoms need $2 \times 3 = 6$ hydrogen atoms: C_3H_6 . C_3H_8 is the formula of propane, an alkane (ending -ane), so option B mixes the alkene name with an alkane formula.

8

Supplement

Naming organic compounds

[1]

Answer: D**Worked solution**

An ester is named in two parts: first the part from the alcohol (ending -yl), then the part from the acid (ending -oate). In a structural formula written as R-COO-R', the acid part is R-COO (the C=O carbon belongs to the acid) and the alcohol part is the group attached to the single-bonded oxygen. Here the acid part is CH_3CH_2COO : three carbons, so propanoate. The alcohol part is $CH_2CH_2CH_2CH_3$: four carbons, so butyl. The name is butyl propanoate. A common error is to name the parts in the order they are written, which gives the wrong answer "propyl butanoate".

9**Supplement**

Naming organic compounds

[5]

Mark scheme

(a)(i)

[1]

- butane (1)

(a)(ii)

[1]

- but-2-ene (1)

REJECT butene / but-1-ene

(a)(iii)

[1]

- propan-2-ol (1)

REJECT propanol / propan-1-ol

(a)(iv)

[1]

- butanoic acid (1)

REJECT propanoic acid

(b)

[1]

- $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$ (1)

ALLOW $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$ / a correct displayed formula**REJECT** $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$

Worked solution

(a)(i) Four carbon atoms, only single bonds: butane.

(a)(ii) Four carbon atoms with a $\text{C}=\text{C}$ between the second and third carbon: but-2-ene. The number is needed because but-1-ene is a different compound.(a)(iii) Three carbon atoms with the $-\text{OH}$ on the middle (second) carbon: propan-2-ol.(a)(iv) Count every carbon atom, including the one in $-\text{COOH}$: CH_3 , CH_2 , CH_2 and COOH make four, so this is butanoic acid.(b) Butan-2-ol has a chain of four carbon atoms with the $-\text{OH}$ on the second carbon: $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$.

10**Core**

Fuels

[1]

Answer: C

Worked solution

Petroleum (crude oil) is a fossil fuel made of many different hydrocarbons mixed together, which is why it can be separated into fractions by fractional distillation. A hydrocarbon is a compound containing hydrogen and carbon only. Do not confuse petroleum with natural gas, which is mainly methane.

11**Core**

Fuels

[1]

Answer: A

Worked solution

The column is hottest at the bottom and coolest at the top. Only substances with low boiling points stay as vapour all the way to the top, and low boiling points go with short chains (small molecules). Short-chain fractions also flow easily, so their viscosity is low. All three properties therefore change together: going up the column, chain length decreases, boiling point decreases and viscosity decreases.

12**Core**

Fuels

[6]

Mark scheme

(a)

[3]

- petroleum is heated so that it vaporises / boils / turns to vapour (1)
- the column has a temperature gradient: hot at the bottom and cooler at the top (1)
- (vapours rise and) fractions condense at different heights / levels according to their boiling points (1)

ALLOW fractions with lower boiling points condense higher up the column

IGNORE references to cracking

(b)(i)

[1]

- kerosene / paraffin (1)

(b)(ii)

[1]

- bitumen (1)

(b)(iii)

[1]

- naphtha (1)
-

Worked solution

(a) The petroleum is heated until most of it turns into vapour and it enters the bottom of the fractionating column. The column is hot at the bottom and gets cooler towards the top. As the vapours rise, each substance condenses when it reaches a level that is cooler than its boiling point. Substances with high boiling points condense low down; substances with low boiling points rise further before condensing. Each fraction is collected at a different height.

(b) Kerosene (paraffin) is used for jet fuel, bitumen is used for making roads, and naphtha is used as a chemical feedstock for making other chemicals.

Mark scheme

(a)(i) [1]

- P (1)

(a)(ii) [1]

- P, Q, S, R (1)

(b) [2]

- P (1)
- it has the lowest boiling (range) / smallest number of carbon atoms per molecule / shortest chains (1)
- the second mark depends on the first

(c) [1]

- $C_{12}H_{26}$ (1)

(d)(i) [1]

- coal (1)

(d)(ii) [1]

- methane / CH_4 (1)

Worked solution

(a)(i) The fraction with the lowest boiling range, P (below 40 °C), rises furthest up the column, so it is collected at the top.

(a)(ii) Viscosity increases as chain length increases. Put the fractions in order of increasing number of carbon atoms: P (1–4), Q (10–16), S (14–20), R (more than 35).

(b) Volatility means how easily a substance turns into a vapour. The fraction with the lowest boiling range and the shortest chains, P, is the most volatile.

(c) Alkanes have the general formula C_nH_{2n+2} . With $n = 12$, $2 \times 12 + 2 = 26$, so the formula is $C_{12}H_{26}$.

(d) The three fossil fuels are coal, natural gas and petroleum, so the missing one is coal. Natural gas consists mainly of methane, CH_4 .

Answer: D

Worked solution

In a substitution reaction, one atom or group of atoms is replaced by another. Here a chlorine atom replaces one hydrogen atom in ethane: $\text{C}_2\text{H}_6 + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{HCl}$. The hydrogen atom that is removed joins with the other chlorine atom to form HCl, not H_2 . Energy from the ultraviolet light is needed to start the reaction; it provides the activation energy.

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Mark scheme

(a) [2]

- contains (the elements) carbon and hydrogen only (1)
 - (all carbon-carbon bonds are) single bonds only / no C=C double bonds (1)
- REJECT** "contains hydrogen and carbon atoms" without "only" for the first mark

(b) [2]

- combustion / burning (1)
- substitution (with chlorine) (1)

(c)(i) [1]

- $\text{C}_3\text{H}_8 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_7\text{Cl} + \text{HCl}$ (1)

(c)(ii) [2]

- $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ (1)
- $\text{CH}_3\text{CHClCH}_3$ (1)

ALLOW $\text{ClCH}_2\text{CH}_2\text{CH}_3$ / $\text{CH}_3\text{CH}(\text{Cl})\text{CH}_3$ / correct displayed formulae

REJECT two ways of writing the same compound (e.g. $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ and $\text{ClCH}_2\text{CH}_2\text{CH}_3$) for both marks — award 1 only

(c)(iii) [1]

- provides the activation energy (1)

ALLOW provides energy to start the reaction

REJECT catalyst

Worked solution

(a) "Hydrocarbon" means the compound contains hydrogen and carbon only. "Saturated" means all of its carbon-carbon bonds are single bonds. Propane, $\text{CH}_3\text{CH}_2\text{CH}_3$, fits both descriptions.

(b) Alkanes are generally unreactive, but they do burn (combustion) and they undergo substitution with chlorine.

(c)(i) One H atom is swapped for one Cl atom, and the removed H joins the other Cl atom: $\text{C}_3\text{H}_8 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_7\text{Cl} + \text{HCl}$. Check: 3 C, 8 H and 2 Cl on each side.

(c)(ii) Propane has two kinds of carbon atom: the two end carbons and the middle carbon. Replacing an H on an end carbon gives $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ (1-chloropropane). Replacing an H on the middle carbon gives $\text{CH}_3\text{CHClCH}_3$ (2-chloropropane). Replacing an H on the other end carbon gives the same compound as the first one, so there are only two products.

(c)(iii) This is a photochemical reaction. The ultraviolet light provides the activation energy. It is not a catalyst.

16**Core**

Alkenes

[1]

Answer: B

Worked solution

Aqueous bromine is orange (it is sometimes described as yellow or brown). An alkene has a C=C double bond, and bromine adds across it, forming a colourless product, so the mixture becomes colourless. An alkane has only single bonds and cannot undergo this addition reaction, so no change is seen and the mixture stays orange. This is the test that distinguishes saturated from unsaturated hydrocarbons.

17**Supplement**

Alkenes

[1]

Answer: C

Worked solution

Butane has two more hydrogen atoms than but-2-ene (C_4H_{10} compared with C_4H_8), so the reagent needed is hydrogen. The addition of hydrogen to an alkene needs a nickel catalyst: $CH_3CH=CHCH_3 + H_2 \rightarrow CH_3CH_2CH_2CH_3$. The other addition reactions add Br_2 or H_2O instead, so they produce compounds containing bromine or oxygen.

Mark scheme

(a) [2]

- high temperature (1)
- catalyst (1)

IGNORE named catalysts or specific temperatures

REJECT high pressure as a condition instead of either mark

(b) [1]

- C_2H_4 (1)

(c) [1]

- H_2 (1)

(d) [2]

Any two from:

- demand for short-chain hydrocarbons / smaller alkanes / petrol / gasoline is greater than the supply from fractional distillation (1)
- there is more supply of long-chain alkanes than is needed / long-chain alkanes are less useful (1)
- to produce alkenes (1) which are used to make polymers / plastics / other chemicals (1)
- to produce hydrogen (1)

ALLOW the second marking point linked to the alkenes point as one of the two reasons, max 2

Worked solution

(a) Cracking breaks large alkane molecules into smaller ones using a high temperature and a catalyst.

(b) Balance the atoms. Carbon: $10 - 8 = 2$. Hydrogen: $22 - 18 = 4$. The missing product is C_2H_4 (ethene), which is an alkene.

(c) Carbon: $4 + (2 \times 3) = 10$, so all the carbon is used. Hydrogen: $8 + (2 \times 6) = 20$, so $22 - 20 = 2$ hydrogen atoms are left, which form H_2 . Cracking can make hydrogen as well as alkenes.

(d) Fractional distillation produces more long-chain alkanes than are needed and less petrol than people want. Cracking converts the less useful long chains into shorter, more useful fuels such as petrol. It also produces alkenes, which are used to make polymers and other chemicals, and it can produce hydrogen.

Mark scheme

(a) [1]

- only one product is formed (1)

(b)(i) [1]

- $\text{CH}_3\text{CHBrCHBrCH}_3$ (1)

ALLOW $\text{CH}_3\text{CH}(\text{Br})\text{CH}(\text{Br})\text{CH}_3$ / a correct displayed formula

(b)(ii) [1]

- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ (1)

(b)(iii) [1]

- $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$ (1)

ALLOW $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$ / a correct displayed formula

REJECT $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$

(b)(iv) [1]

- butan-2-ol (1)

ECF the correct name for the structure given in (b)(iii)

REJECT butanol / butan-1-ol unless ECF applies

(c) [2]

- but-2-ene is unsaturated / has a $\text{C}=\text{C}$ double bond, so bromine can add across the double bond (1)
- butane is saturated / has only (carbon-carbon) single bonds, so addition is not possible (1)

ALLOW "butane is unreactive" only with reference to single bonds

IGNORE references to ultraviolet light

Worked solution

(a) In an addition reaction, the reactants join together to form only one product.

(b) In each addition, the $\text{C}=\text{C}$ double bond becomes a single bond and one new atom or group is added to each of the two carbon atoms that were joined by the double bond (carbons 2 and 3).

(i) Bromine adds one Br to each: $\text{CH}_3\text{CHBrCHBrCH}_3$.

(ii) Hydrogen adds one H to each: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$, butane.

(iii) Steam adds H to one carbon and OH to the other: $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$.

(iv) Because the double bond is in the middle of a symmetrical molecule, the $-\text{OH}$ always ends up on the second carbon atom, so the product is butan-2-ol.

(c) The C=C double bond in but-2-ene lets bromine add to it. Butane has only single bonds (it is saturated), so it cannot take part in addition reactions; it only reacts with chlorine or bromine by substitution in ultraviolet light.

20

Core

Alcohols

[1]

Answer: A

Worked solution

Yeast contains enzymes that convert glucose to ethanol and carbon dioxide. The temperature must be warm but not hot (25–35 °C), because at high temperatures such as 80 °C the yeast dies. Oxygen must be kept out (anaerobic conditions); otherwise the ethanol is not produced and any ethanol can be oxidised. The conditions 300 °C, 6000 kPa and an acid catalyst are for the catalytic addition of steam to ethene, a different method.

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Mark scheme

(a)

[2]

- (as a) solvent (1)
- (as a) fuel (1)

IGNORE named examples such as "in perfumes" or "for cars" if the use is also given

REJECT "drinks" / "alcoholic drinks" as one of the two uses

(b)

[2]

- $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$
- correct formulae of all reactants and products (1)
- correct balancing (1)

ALLOW $\text{CH}_3\text{CH}_2\text{OH}$ / $\text{C}_2\text{H}_6\text{O}$ for ethanol

ALLOW multiples, e.g. $2\text{C}_2\text{H}_5\text{OH} + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$

(c)

[1]

- carbon monoxide / CO (1)

IGNORE soot / carbon (not a gas)

REJECT carbon dioxide

(d)

[1]

- carbon dioxide / CO_2 (1)

Worked solution

(a) Ethanol is used as a solvent and as a fuel.

(b) Complete combustion of any compound of carbon, hydrogen and oxygen gives carbon dioxide and water. Balance carbon first: 2 C in ethanol gives 2CO_2 . Then hydrogen: 6 H in ethanol gives $3\text{H}_2\text{O}$. Then count oxygen on the right: $(2 \times 2) + 3 = 7$. Ethanol already provides 1 O, so 6 more O atoms are needed, which is 3O_2 . $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$. Check: C 2 = 2; H 6 = 6; O 7 = 7.

(c) With too little oxygen, combustion is incomplete and carbon monoxide can form. Carbon monoxide is toxic.

(d) Yeast converts glucose into ethanol and carbon dioxide: $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$.

Mark scheme

(a)

[2]

Any two from:

- (temperature of) 300 °C (1)
- (pressure of) 6000 kPa / 60 atm (1)
- acid catalyst (1)

ALLOW any temperature in the range 250–350 °C and any pressure 50–70 atm / 5000–7000 kPa**ALLOW** phosphoric acid for acid catalyst

- max 2

(b)

[1]

- $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$ (1)

ALLOW $\text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{OH}$ **IGNORE** state symbols

(c)

[4]

Advantages of method 1 (fermentation), any two from:

- uses a renewable raw material / sugar cane can be regrown (1)
- low temperature / uses less energy (1)
- does not use petroleum, which will run out / is non-renewable (1)
- sugar cane absorbs carbon dioxide as it grows (1)
- simple / cheap equipment, no high pressure needed (1)

Disadvantages of method 1 (fermentation), any two from:

- slow (reaction) (1)
- batch process (not continuous) (1)
- ethanol produced is not pure / is a dilute solution, so it must be separated by (fractional) distillation (1)
- needs large areas of land (that could grow food) (1)
- lower yield / less ethanol produced for the same time (1)
- max 2 marks for advantages and max 2 marks for disadvantages

ALLOW disadvantages of method 2 given as advantages of method 1 when the comparison is clear (e.g. "method 2 uses a non-renewable resource")**Worked solution**

(a) In method 2, ethene and steam are passed over an acid catalyst at about 300 °C and 6000 kPa (60 atm).

(b) One molecule of steam adds across the C=C double bond: $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$. Only one product is formed, so this is an addition reaction.

(c) Fermentation uses sugar from a crop, which is renewable, and it needs only a warm temperature (25–35 °C), so it uses much less energy than method 2. Method 2 depends on ethene from petroleum, which is non-renewable. However, fermentation is slow and is done in batches, and it gives a dilute, impure solution of ethanol that has to be fractionally distilled. Method 2 is fast, continuous and gives much purer ethanol.

23

Core

Carboxylic acids

[1]

Answer: B

Worked solution

Ethanoic acid reacts with carbonates like other acids: acid + carbonate → salt + water + carbon dioxide. The salt is calcium ethanoate. To write its formula, balance the charges: Ca^{2+} needs two CH_3COO^- ions, giving $(\text{CH}_3\text{COO})_2\text{Ca}$ (also written $\text{Ca}(\text{CH}_3\text{COO})_2$). Hydrogen gas is given off when an acid reacts with a reactive metal such as magnesium, not with a carbonate.

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Mark scheme

(a) [2]

- purple (at the start) (1)
- to colourless (1)

ALLOW pink for purple

REJECT "clear" for colourless

(b) [1]

- by bacteria / bacterial oxidation (in air) (1)

ALLOW microbial oxidation / oxidation by microorganisms

REJECT fermentation by yeast

(c) [2]

- zinc ethanoate (1)
- hydrogen (1)

REJECT water as one of the two products

(d)(i) [1]

- methyl ethanoate (1)

REJECT ethyl methanoate

(d)(ii) [1]

- $\text{CH}_3\text{COOCH}_3$ (1)

ECF the correct structural formula for the name given in (d)(i)

ALLOW a correct displayed formula

(d)(iii) [1]

- water / H_2O (1)

Worked solution

(a) Acidified potassium manganate(VII) is purple. It is an oxidising agent: as it oxidises ethanol, it is reduced and the purple colour disappears, leaving a colourless solution.

(b) In vinegar production, bacteria oxidise ethanol to ethanoic acid using oxygen from the air.

(c) Ethanoic acid reacts with a reactive metal like other acids: acid + metal $\rightarrow$ salt + hydrogen. Here zinc + ethanoic acid $\rightarrow$ zinc ethanoate + hydrogen.

(d) A carboxylic acid and an alcohol react (with an acid catalyst) to form an ester and water. Name the alcohol part first (methanol gives "methyl") and the acid part second (ethanoic acid gives "ethanoate"): methyl ethanoate. The structural formula is $\text{CH}_3\text{COOCH}_3$; the CH_3COO part comes from the acid, and the

CH₃ attached to the single-bonded oxygen comes from the alcohol. $\text{CH}_3\text{COOH} + \text{CH}_3\text{OH} \rightarrow \text{CH}_3\text{COOCH}_3 + \text{H}_2\text{O}$.

25 Core Polymers

[1]

Answer: B

Worked solution

"Poly" means many. A polymer is a very large molecule made when many small molecules, the monomers, join together. For example, many ethene molecules join to form poly(ethene). Plastics are made from polymers, so their monomers have already been joined.

26 Supplement Polymers

[1]

Answer: D

Worked solution

In addition polymerisation, the C=C double bond of each monomer opens up and the monomers join into a long chain. Working backwards, the repeat unit $-\text{[CH}_2\text{-CHCl]}-$ has two carbon atoms in the main chain: one with two H atoms, and one with one H and one Cl. The monomer has exactly the same atoms on each carbon, joined by a double bond: $\text{CH}_2=\text{CHCl}$ (chloroethene). Always check that the groups on each carbon in the monomer match the groups in the repeat unit.

27 Supplement Polymers

[1]

Answer: A

Worked solution

In addition polymerisation, monomers with a C=C double bond join together and nothing else is made, so the polymer is the only product. In condensation polymerisation, two different functional groups react (for example $-\text{COOH}$ with $-\text{OH}$ or with $-\text{NH}_2$) and each time they join, a small molecule such as water is removed. The linkages formed are ester linkages (in polyesters) or amide linkages (in polyamides).

Mark scheme

(a) [2]

- many ethene molecules / monomers join together (to form a long chain) (1)
 - the C=C double bond breaks / opens (addition polymerisation) (1)
- ALLOW** "addition polymerisation" for the second mark if linked to the double bond
- REJECT** water / small molecule formed

(b) [2]

- poly(ethene) does not decompose / break down / rot (for a very long time) (1)
 - so landfill sites fill up / more land is needed for landfill (1)
- ALLOW** remains in the ground for hundreds of years for the first mark

(c) [1]

Any one from:

- sea animals / birds eat it / swallow it (and die) (1)
- sea animals become trapped / entangled in it (1)
- it breaks into small pieces (microplastics) that enter food chains (1)

(d) [1]

- toxic gases are produced (1)
- ALLOW** named toxic gas, e.g. carbon monoxide, hydrogen chloride
- REJECT** "releases carbon dioxide" alone

Worked solution

(a) Poly(ethene) is made by addition polymerisation. The C=C double bond in each ethene molecule opens, and very many ethene molecules join together into a long chain. No other product is formed.

(b) Because poly(ethene) is unreactive and non-biodegradable, it does not break down when buried. It stays in landfill for a very long time, so landfill sites fill up and more land has to be used.

(c) Plastic waste builds up in the oceans. Animals can swallow it or get trapped in it, and it breaks into tiny pieces that can enter food chains.

(d) When plastics are burned, toxic gases such as carbon monoxide (and, from some plastics, hydrogen chloride) can be produced, which harm people and the environment.

Mark scheme

(a)(i) [1]

- condensation (polymerisation) (1)

(a)(ii) [1]

- water / H₂O (1)

(b) [2]

- [OC-CH₂-CH₂-CO-O-CH₂-CH₂-O]- (2)

ALLOW -[CO-CH₂CH₂-COO-CH₂CH₂-O]- / -[O-CH₂CH₂-O-CO-CH₂CH₂-CO]- / a correct displayed formula

- an ester linkage -COO- shown correctly between the two monomer parts, but the rest of the repeat unit incorrect (1)

REJECT repeat units that still show -OH or -COOH end groups, max 1

(c) [1]

- ester (1)

(d) [1]

- CONH- (1)

ALLOW -NHCO- / -CO-NH- / -C(=O)-N(H)- / a correct displayed formula of the amide linkage

Worked solution

(a) Each monomer has two functional groups (two -COOH groups or two -OH groups). When a -COOH group reacts with an -OH group, an ester linkage forms and a water molecule is removed. This is condensation polymerisation.

(b) Remove H from the -OH of the diol and OH from the -COOH of the acid, then join them. The acid part becomes -CO-CH₂-CH₂-CO- and the diol part becomes -O-CH₂-CH₂-O-. Joining one of each gives the repeat unit -[CO-CH₂-CH₂-CO-O-CH₂-CH₂-O]-. Each end bond links to the next repeat unit. One repeat unit contains one acid part and one diol part.

(c) The -CO-O- group joining the parts is an ester linkage, so this polymer is a polyester.

(d) With a diamine instead of a diol, the -COOH group reacts with -NH₂ and water is again removed. The linkage formed is the amide linkage, -CO-NH-, so the polymer is a polyamide.

Mark scheme

(a) [2]

- $-\text{CH}_2-\text{CH}(\text{CH}_3)-$ (2)

ALLOW $-\text{CH}(\text{CH}_3)-\text{CH}_2-$ / a correct displayed formula with continuation bonds

- main chain of two carbon atoms only, with CH_3 as a side group, but missing continuation bonds or brackets (1)

REJECT $-\text{CH}_2-\text{CH}_2-\text{CH}_2-$ / a $\text{C}=\text{C}$ double bond in the repeat unit, 0 marks

(b) [1]

- $\text{CF}_2=\text{CF}_2$ (1)

(c) [2]

- PET is converted / broken down back into its monomers (1)
- the monomers are re-polymerised (to make new PET) (1)

Worked solution

(a) In propene, $\text{CH}_2=\text{CH}-\text{CH}_3$, only the two carbon atoms joined by the double bond become part of the main chain. The CH_3 group becomes a side branch. When the double bond opens, the repeat unit is $-\text{CH}_2-\text{CH}(\text{CH}_3)-$, with a bond at each end linking to the next unit. A common error is to put all three carbon atoms in the chain.

(b) Work backwards: put a double bond between the two carbon atoms of the repeat unit, keeping the same atoms on each carbon. The monomer is $\text{CF}_2=\text{CF}_2$ (tetrafluoroethene).

(c) PET is a condensation polymer. It can be converted back into its monomers, and these monomers can then be re-polymerised to make new PET.