OCR A-Level Chemistry A

Module 6: Organic chemistry and analysis mark scheme · goes with “Module 6: Organic chemistry and analysis” · whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/

Mark schemes

6 topics · 94 questions

Q1 · Amines, amino acids and polymers · [14 marks]

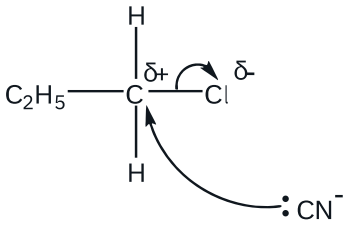
OCR MARK SCHEME

18(a)(i)

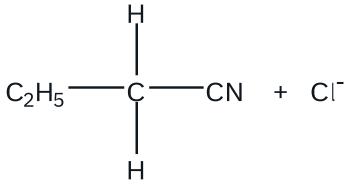
curly arrow from $^{-}$CN to carbon atom of C–Cl bond ✓

Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$,

AND curly arrow from C–Cl bond to Cl atom ✓



correct organic product **AND** Cl^{-} ✓



[3 marks]

EXAMINER GUIDANCE

Curly arrow must come from lone pair on C of $^{-}$CN **OR** CN^{-}

OR from minus sign on C of $^{-}$CN ion (then lone pair on CN^{-} does not need to be shown)

IGNORE *NaCl*

ALLOW *S_N1 mechanism:*

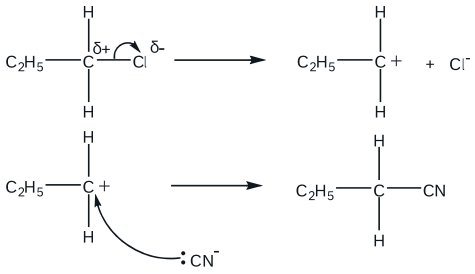
Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$,

AND curly arrow from C–Cl bond to Cl atom ✓

Correct carbocation **AND** curly arrow from $^{-}$CN to carbocation. Curly arrow must come from lone pair on C of $^{-}$CN **OR** CN^{-}

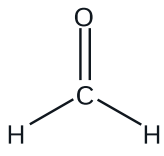
OR from minus sign on C of $^{-}$CN ion (then lone pair on CN^{-} does not need to be shown) ✓

correct organic product **AND** Cl^{-} ✓



18(a)(ii)

Compound G

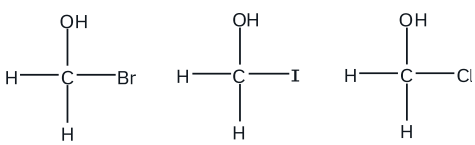


✓

ALLOW *any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

IGNORE *name(s)*

ALLOW



Reagents

Reaction 2: H_2 **AND** Ni ✓

Reaction 3: Correct formula of an aqueous acid

e.g. HCl(aq)/H_2SO_4(aq) ✓

[3 marks]

ALLOW *any suitable metal catalyst e.g. Pt*

ALLOW *$LiAlH_4$ for reagent in reaction 2*

DO NOT ALLOW *$NaBH_4$ for reagent in reaction 2*

IGNORE *names (question asks for formulae)*

IGNORE *references to temperature and/or pressure*

ALLOW *$H^+(aq)$*

IGNORE *dilute*

ALLOW *formula of an acid* ***AND*** *water*

e.g. HCl **AND** H_2O

H_2SO_4 **AND** H_2O

18(a)(iii)

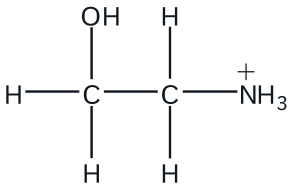
Explanation

Nitrogen electron pair **OR** nitrogen lone pair

AND

accepts a proton/H^+ ✓

Structure of salt



AND Cl^- ✓

[2 marks]

IGNORE *NH_2 group donates electron pair*

ALLOW *nitrogen donates an electron pair to H^+*

DO NOT ALLOW *nitrogen donates lone pair to acid*

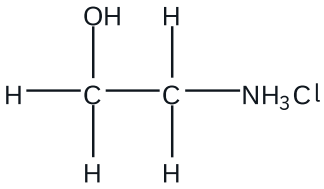
IGNORE *comments about the O in the –OH group*

Compound H is a base is not sufficient (role of lone pair required)

DO NOT ALLOW *nitrogen/N lone pair accepts hydrogen (proton/H^+ required)*

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW



i.e. charges not required

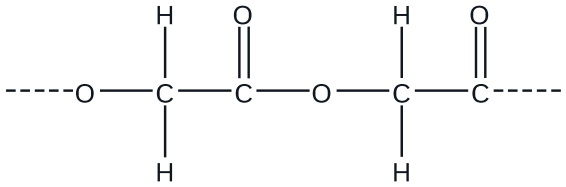
IF *charges are shown both need to be present*

ALLOW *charge either on N atom or NH_3^+*

IF *displayed then + charge must be on the nitrogen*

18(a)(iv)

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*



Ester link ✓

Rest of structure ✓

(polymer J is biodegradable because) the ester / ester bond / ester group / polyester can be hydrolysed ✓

[3 marks]

DO NOT ALLOW *more than two repeat units for second marking point.*

'End bonds' MUST be shown (do not have to be dotted)

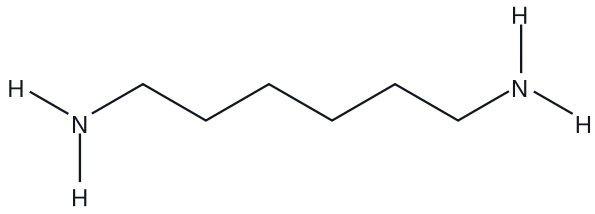
IGNORE *brackets*

IGNORE *n*

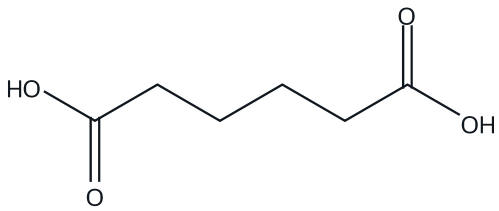
Broken down by water is not sufficient

IGNORE *references to photodegradable*

18(b)(i)



✓

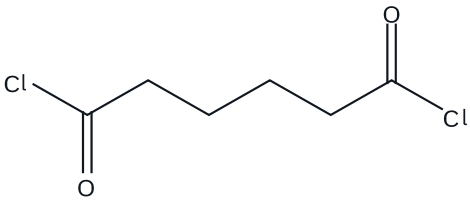


✓

[2 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW



18(b)(ii)

(*n* = 21500 / 226 =) 95 (repeat units) ✓

[1 mark]

MUST be a whole number.

DO NOT ALLOW *an answer that uses an incorrect molar mass in the working.*

ALLOW *96*

Q2 · Amines, amino acids and polymers · [1 mark]

Answer: **A**

Q3 · Amines, amino acids and polymers · [1 mark]

Answer: **C**

OCR MARK SCHEME

4

EXAMINER GUIDANCE

ALLOW *4 (This is the number of chiral centres)*

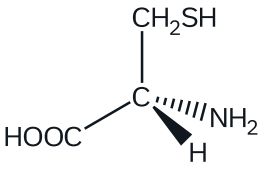
Q4 · Amines, amino acids and polymers · [7 marks]

OCR MARK SCHEME

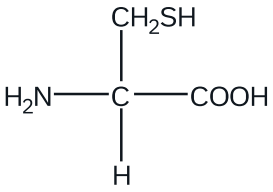
EXAMINER GUIDANCE

17(a)

Correct groups attached to chiral C of cysteine seen once e.g.

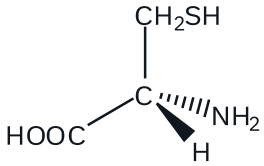


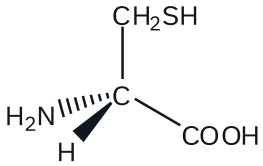
OR



✓

Two 3D structures of cysteine that are mirror images with correct connectivity in both ✓





[2 marks]

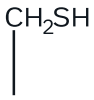
Each structure must have four central bonds with at least two wedges.

For bond into paper accept:



ALLOW *bond to any part of the CH_2 of the CH_2SH group*

e.g. **ALLOW**

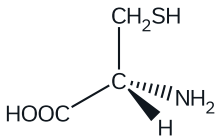


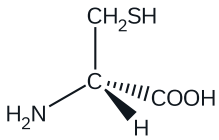
OR



ALLOW *two 3D structures with 2 groups swapped*

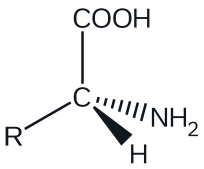
e.g.

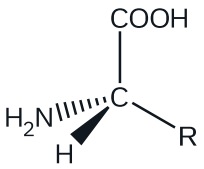




IF *CH_2SH is shown as 'R'* ***ALLOW*** *1 mark for two 3D structures with correct connectivity that are mirror images*

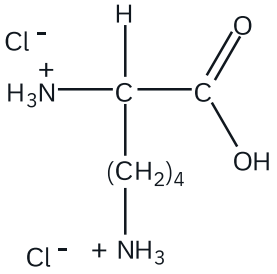
e.g.





17(b)

Correct salt of lysine with both amine groups protonated



✓✓

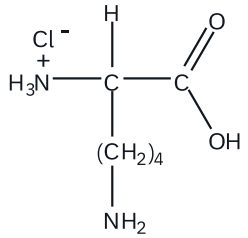
ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

Note: Cl^- is required (question asks for salt)

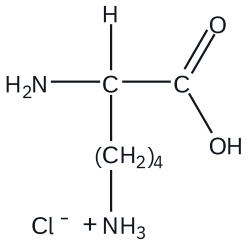
ALLOW *NH_3Cl i.e charges not required*

ALLOW *1 mark for*

[2 marks]



OR



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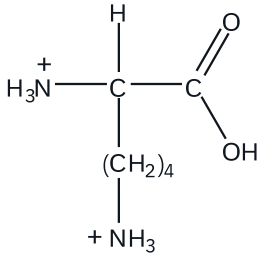
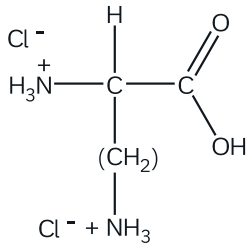


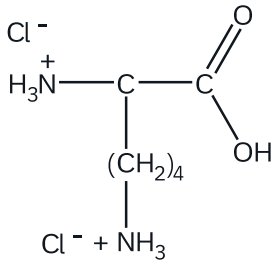
i.e. no Cl^-

IF *there is a small slip in the structure*
ALLOW 1 mark *for diammonium salt e.g*



(incorrect number of CH_2 in R group)

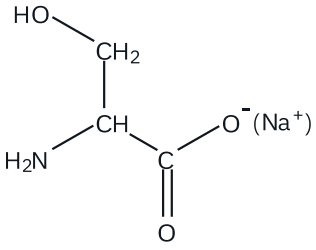
OR



(H missing from α C atom)

17(c)

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*



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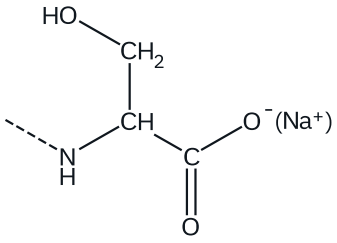
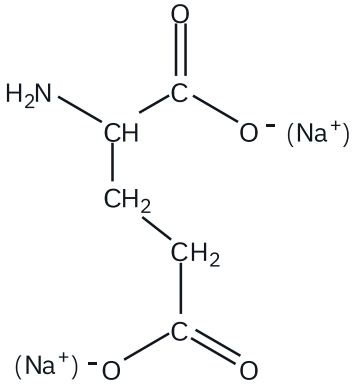


✓



✓✓

i.e. one mark for each group hydrolysed

[3 marks]

IGNORE *NH_3 (question asks for organic products)*

ALLOW *$–COO^-$* ***OR*** *–COONa*

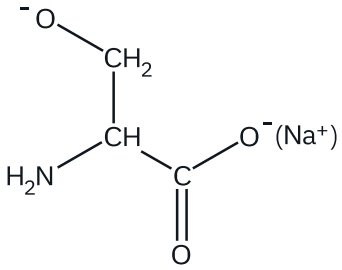
DO NOT ALLOW *negative charge on C atom*

DO NOT ALLOW *–COO–Na (covalent bond)* ***BUT ALLOW ECF*** *if seen in subsequent structures*

DO NOT ALLOW *COOH in this structure*

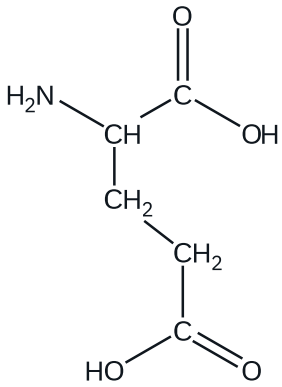
DO NOT ALLOW *(sodium) salt of alcohol group*

i.e.



ALLOW *COOH groups in this structure*

i.e. award 2 marks for



IGNORE *small slip in carbon chain*

Q5 · Amines, amino acids and polymers · [1 mark]

Answer: **C**

Q6 · Amines, amino acids and polymers · [1 mark]

Answer: **B**

OCR MARK SCHEME

6

EXAMINER GUIDANCE

ALLOW *6 (This is the number of chiral centres)*

Q7 · Amines, amino acids and polymers · [1 mark]

Answer: **A**

Q8 · Amines, amino acids and polymers · [1 mark]

Answer: **D**

OCR MARK SCHEME

8

EXAMINER GUIDANCE

ALLOW *8 (correct number of chiral centres)*

Q9 · Amines, amino acids and polymers · [9 marks]

OCR MARK SCHEME

21(a)

Non-superimposable mirror images (about a chiral centre) ✓

[1 mark]

EXAMINER GUIDANCE

IGNORE *definition of stereoisomers*

21(b)(i)

2-amino-3-methylbutanoic acid

OR

3-methyl-2-aminobutanoic acid ✓

[1 mark]

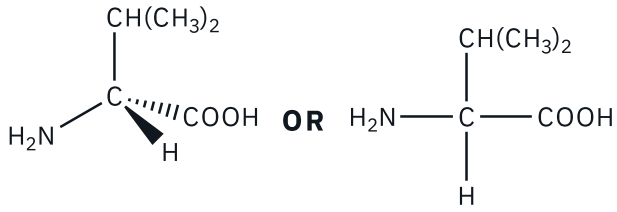
IGNORE *lack of hyphens, extra hyphens, or addition of commas*

DO NOT ALLOW *the following for methyl: methy, meth, methly*

DO NOT ALLOW *the following for amino: amine, amin*

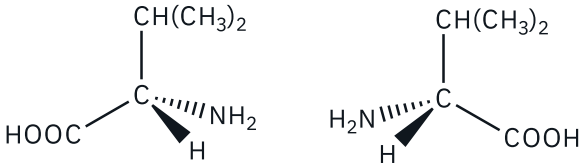
21(b)(ii)

Correct groups attached to chiral C of valine seen once e.g.



✓

Two 3D structures of valine that are mirror images with correct connectivity in both ✓

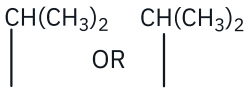


[2 marks]

ALLOW *any combination of skeletal OR structural OR displayed formula as long as unambiguous*

IGNORE *connectivity for the first marking point but must be correct for the second mark.*

ALLOW *bond to any part of the CH of the* $CH(CH_3)_2$ *group e.g.* ***ALLOW***



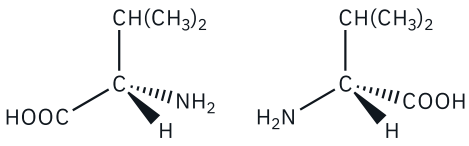
Each structure must have four central bonds with at least two wedges.

For bond into paper accept:



ALLOW *two 3D structures with 2 groups swapped*

e.g.



ALLOW *R or* C_3H_7 *to be shown for* $CH(CH_3)_2$ *for second mark only.*

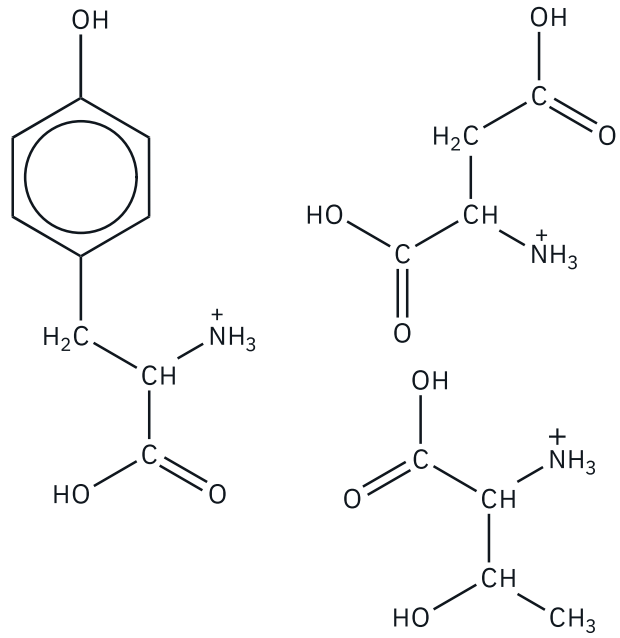
ALLOW ECF *for second mark for small slips such as missing H e.g. $C(CH_3)_2$*

21(c)(i)

16 ✓

[1 mark]

21(c)(ii)



ALLOW *any combination of skeletal OR structural OR displayed formula as long as unambiguous*

IGNORE *connectivity*

ALLOW *+ charge on H of NH_3 group, i.e. NH_3^+*

If structures are shown with NH_3 groups (without the + charge) OR as NH_2^+ groups allow ***ECF*** *for subsequent use.*

ALLOW *structures shown as correctly balanced salts, e.g NH_3Cl OR $NH_3^+Cl^-$ all marks can be awarded.*

1 mark for each correct structure with

- Either NH_3^+ OR NH_2 ✓✓✓

1 mark for

- all 3 correct structures with NH_3^+ ✓

[4 marks]

Q10 · Amines, amino acids and polymers · [6 marks]

OCR MARK SCHEME

3

Level 3 (5–6 marks)

Suggests ALL of the following

- Reagents and conditions for 3 functional groups
- Products for 3 functional groups
- Optical isomerism with description and 3D optical isomers shown

There is a well-developed line of reasoning which is clear and logically structured.

The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Suggests two of the following

EXAMINER GUIDANCE

CHECK TOP OF QUESTION FOR RESPONSES

Indicative scientific points may include:

Stereoisomerism

- Optical isomerism identified with description: e.g. chiral centre /non-superimposable mirror images
- 3D Optical isomers drawn, e.g.

- Reagents and conditions for 2 functional groups
- Products for 2 functional groups
- Optical isomerism with description OR an attempt to show 3D optical isomers

There is a line of reasoning presented with some structure.

The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Suggests two of the following

- Reagents and conditions for 1 functional group
- Products for 1 functional group
- Identifies optical isomerism with description OR an attempt to show 3D optical isomers

There is an attempt at a logical structure with a line of reasoning.

The information is in the most part relevant.

0 marks No response or no response worthy of credit.

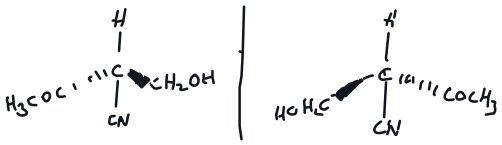
Key points to check

CHECK TOP OF QUESTION for responses

IGNORE CONNECTIVITY

in 3D isomer structures

- IGNORE bond angles
- Wedges needed
- ALLOW



Some responses will not fit into this exact pattern and a best-fit match may be needed

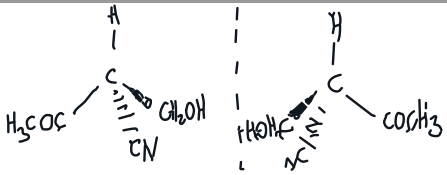
Clear communication

Focus on

- Clear diagrams of 3D optical isomers
- Diagrams of unambiguous structures
- Reagents and functional group formed are linked
- Communication is more a general feel for the quality of the responses.

Slips and minor errors in structures

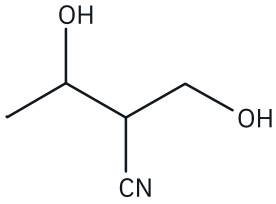
- Do not penalise the odd slip or omission, e.g. An extra C in a chain; a C short in a chain, C shown instead of CH_2 or skeletal
- You need to judge the extent of any slip based on the whole response. Remember that each candidate response is unique.



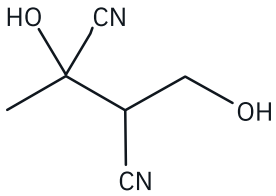
Description is subsumed in 3D diagrams

Reactions of ketone/carbonyl e.g.

$NaBH_4$

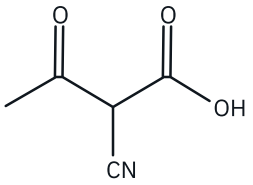


HCN OR CN^-/H^+ (e.g. $NaCN/H^+$)

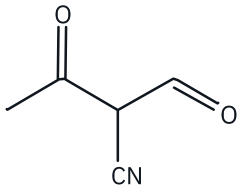


Reactions of –OH, e.g.

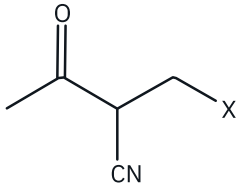
$H^+/Cr_2O_7^{2-}$ OR $H_2SO_4/K_2Cr_2O_7$ reflux



$H^+/Cr_2O_7^{2-}$ OR $H_2SO_4/K_2Cr_2O_7$ distil



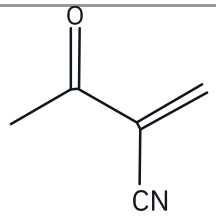
$NaBr/KBr/Br^-$ AND $acid/H^+$ OR HBr



X = halogen

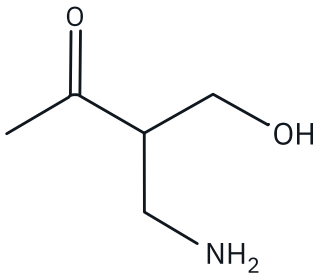
$Acid/H^+$ (catalyst) (e.g. H_2SO_4)

[6 marks]

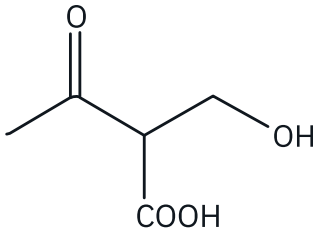


Reactions of C–CN, e.g.

H_2 AND metal catalyst e.g. Ni, Pt, Pd



H^+/H_2O e.g. HCl(aq) or H_2SO_4(aq)



OTHER REAGENTS, CONDITIONS AND PRODUCTS

e.g. $LiAlH_4$ as reagent

Q11 · Amines, amino acids and polymers · [1 mark]

Answer: **A**

OCR MARK SCHEME

HCl

EXAMINER GUIDANCE

ALLOW HCl

Q12 · Amines, amino acids and polymers · [6 marks]

OCR MARK SCHEME

22(a)

***IF** answer on answer line = 73518 AWARD 3 marks*

***IF** answer on answer line = 73500 AWARD 2 marks*

M_r of amino acid = 165 ✓

M_r of 500 molecules = 500 × 165 = 82500 ✓

M_r of polymer = 82500 – (499 × 18) = 73518 ✓

(final answer must be given to nearest whole number)

[3 marks]

EXAMINER GUIDANCE

ALLOW ECF from incorrect M_r of amino acid

Alternative method:

M_r of repeat unit = 147 ✓

147 x 500 = 73500 ✓

73500 + 18 = 73518 ✓

Common error for 2 marks

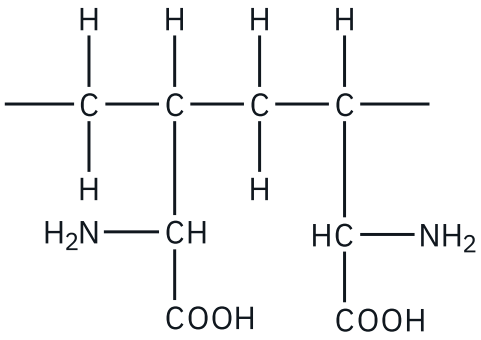
36518 Use of M_r 91

82500 Not shown 165 in working

Common error for 1 mark

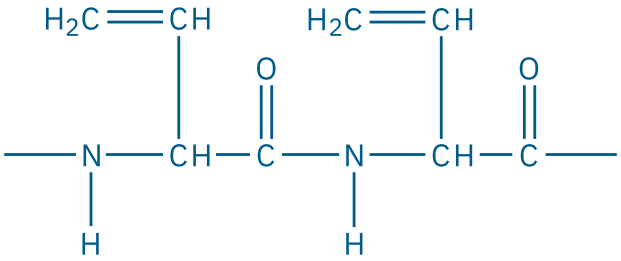
22(b)

Addition polymer



✓

Condensation polymer



Amide link ✓

2 repeat units of correct polymer ✓

[3 marks]

45500 Use of M_r 91

For BOTH structures,

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

'End bonds' MUST be shown (with either a solid or dashed line)

BUT ALLOW ECF **IF** end bonds omitted in both structures

DO NOT ALLOW *more than 2 repeat units*

BUT ALLOW ECF in subsequent structure

IGNORE *connectivity of side groups in both diagrams*

CARE: **ALLOW** any consistent repeat unit: side groups can alternate or be on opposite sides of chain

ALLOW *NH in amide link i.e. without bond shown*

ALLOW *–NH– at either end*

IGNORE *brackets* ***IGNORE*** *n or subscript numbers*

ALLOW *C_2H_3 as side chain for condensation polymer*

ALLOW *1 mark if correct structures given by wrong way round*

Q13 · Amines, amino acids and polymers · [1 mark]

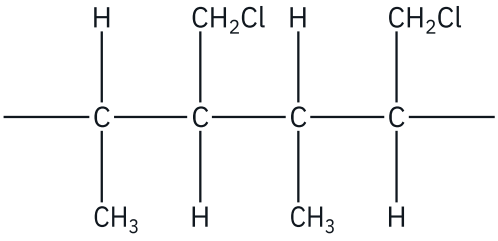
Answer: **C**

Q14 · Amines, amino acids and polymers · [8 marks]

OCR MARK SCHEME

18(a)

Two repeat units of polymer of 1-chlorobut-2-ene



✓

Two repeat units of polymer of 3-hydroxybutanoic acid

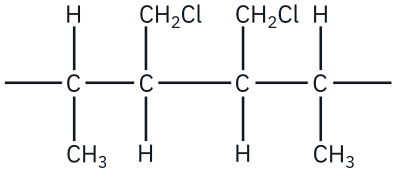
EXAMINER GUIDANCE

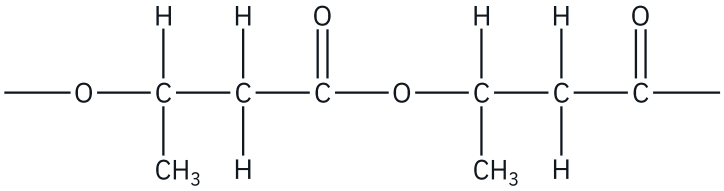
ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

IGNORE *brackets and use of n or subscript numbers*

IGNORE *connectivity*

ALLOW *alternating side chains i.e.*





Ester link shown ✓

Two complete repeat units ✓

Type of polymerisation

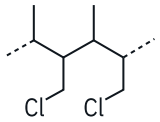
1-chlorobut-2-ene: addition

AND

3-hydroxybutanoic acid: condensation ✓

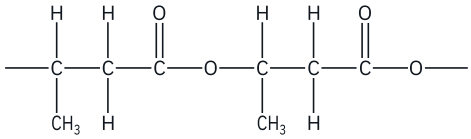
[4 marks]

End bonds MUST be shown (solid or dotted) e.g.

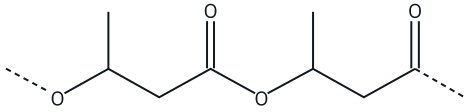


BUT ALLOW ECF IF end bonds omitted in both structures

ALLOW *any whole repeat units e.g.*



End bonds MUST be shown (solid or dotted) e.g.



DO NOT ALLOW *only one repeat unit* ***OR*** *more than 2 repeat units*

BUT ALLOW ECF in subsequent structure

DO NOT ALLOW *'additional'*

18(b)(i)

(Chlorine containing polymers) produces toxic (products when incinerated) ✓

[1 mark]

ALLOW *suitable alternatives for 'produces' e.g. forms, releases (must be clear that it is a product)*

ALLOW *produces HCl /hydrogen chloride/ hydrochloric acid*

ALLOW *'poisonous' for toxic*

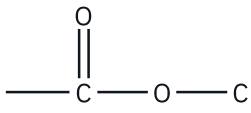
IGNORE *harmful / pollutant / dangerous*

18(b)(ii)

Ester / ester bond / ester group / polyester ✓

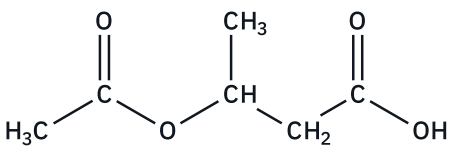
[1 mark]

ALLOW *displayed formula for an ester functional group i.e*



IGNORE *reference to hydrogen bonding*

18(c)

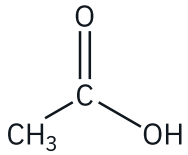


✓

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

e.g. $CH_3COOCH(CH_3)CH_2COOH$ CH_3COOH

ALLOW *products in either box*



✓

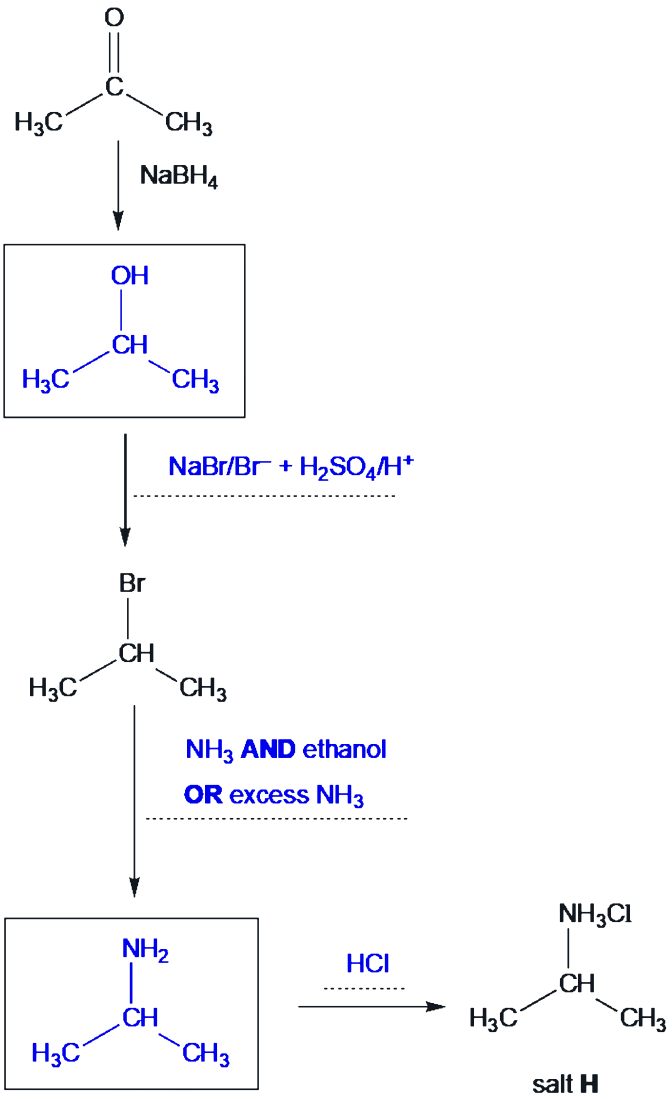
[2 marks]

IGNORE *Connectivity* ***BUT DO NOT ALLOW*** *-HO*

Q15 · Amines, amino acids and polymers · [15 marks]

OCR MARK SCHEME

21(a)



✓✓✓✓✓

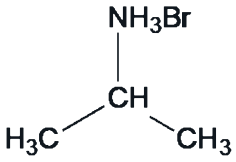
[5 marks]

EXAMINER GUIDANCE

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *HBr*

ALLOW *for the bottom left structure*



21(b)(i)

Ester

Amide

Amine

Carboxylic acid

IGNORE *amino acid*

ALLOW *carboxyl*

IGNORE *attempt to classify amide, e.g. secondary*

IGNORE *formulae (question asks for names)*

4 groups correct ✓✓✓

3 groups correct ✓✓

2 groups correct ✓

[3 marks]

IF > 4 *functional groups are shown,*

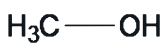
- Count 4 groups max but incorrect groups first

IGNORE *aryl* ***OR*** *alkyl group*

e.g. benzene, phenyl, aryl, arene, methyl

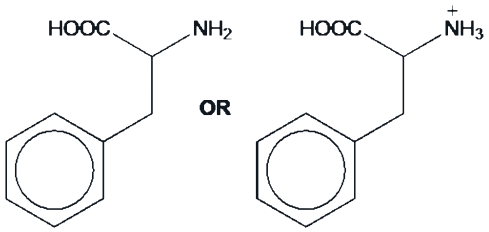
21(b)(ii)

Methanol 1 mark

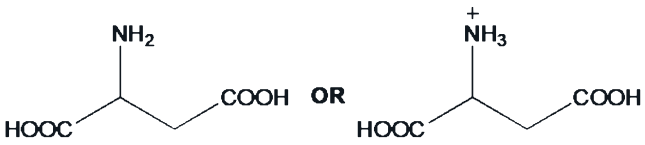


✓

Amino Acids 3 marks



✓



✓

Both amino acids shown with NH_3^+ ✓

[4 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *+ charge on H of NH_3 group, i.e.NH_3^+*

If BOTH amino acids are shown with NH_3 groups (without the + charge) ***OR*** *as NH_2^+ groups, award 2 of the 3 marks for the amino acids*

If BOTH amino acids are shown as correctly balanced salts, e.g NH_3Cl, all marks can be awarded.

21(b)(iii)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = 22.4 OR 22 OR 23 award 3 marks

n(aspartame) in 1 can = $\frac{0.167}{294}$ = 5.68×10^{-4} (mol) ✓

n(aspartame) limit per day = $1.7 \times 10^{-4} \times 75 = 0.01275$ (mol) ✓

number of cans = $\frac{0.01275}{5.68 \times 10^{-4}}$ = 22.4 ✓

[3 marks]

If there is an alternative answer, apply ECF and look for alternative methods

Alternative methods

n(aspartame) in 1 can = $\frac{0.167}{294}$ = 5.68×10^{-4} (mol) ✓

n(aspartame) per kg

= $\frac{5.68 \times 10^{-4}}{75}$ = 7.57×10^{-6} (mol) ✓

number of cans = $\frac{1.7 \times 10^{-4}}{7.57 \times 10^{-6}}$ = 22.4 ✓

OR

n(aspartame) limit per day = $1.7 \times 10^{-4} \times 75$ =0.01275 (mol) ✓

mass(aspartame) limit per day =0.01275 x 294 = 3.7485 (g) ✓

number of cans = $\frac{3.7485}{0.167}$ = 22.4 ✓

Q16 · Amines, amino acids and polymers · [18 marks]

OCR MARK SCHEME

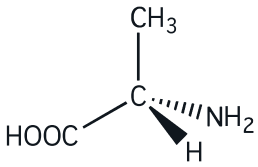
18(a)(i)

Non-superimposable mirror images (about a chiral centre) ✓

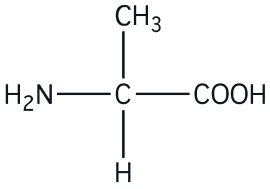
[1 mark]

18(a)(ii)

Correct groups attached to chiral C of alanine seen once e.g.



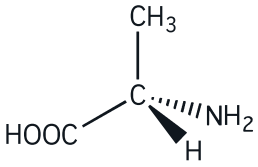
OR

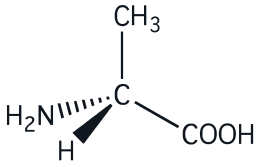


✓

Two 3D structures of alanine that are mirror images **AND** correct connectivity in both

i.e.





✓

[2 marks]

18(a)(iii)

4 ✓

[1 mark]

18(b)

EXAMINER GUIDANCE

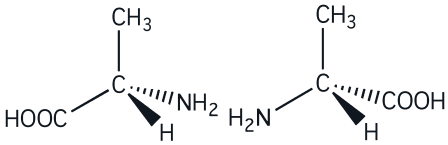
Each structure must have four central bonds with at least two wedges.

For bond into paper accept:



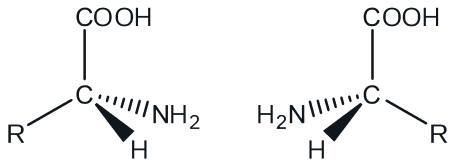
ALLOW *two 3D structures with 2 groups swapped*

e.g.



IF *CH_3 is shown as 'R'* ***ALLOW*** *1 mark for two 3D structures with correct connectivity that are mirror images*

e.g.



ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

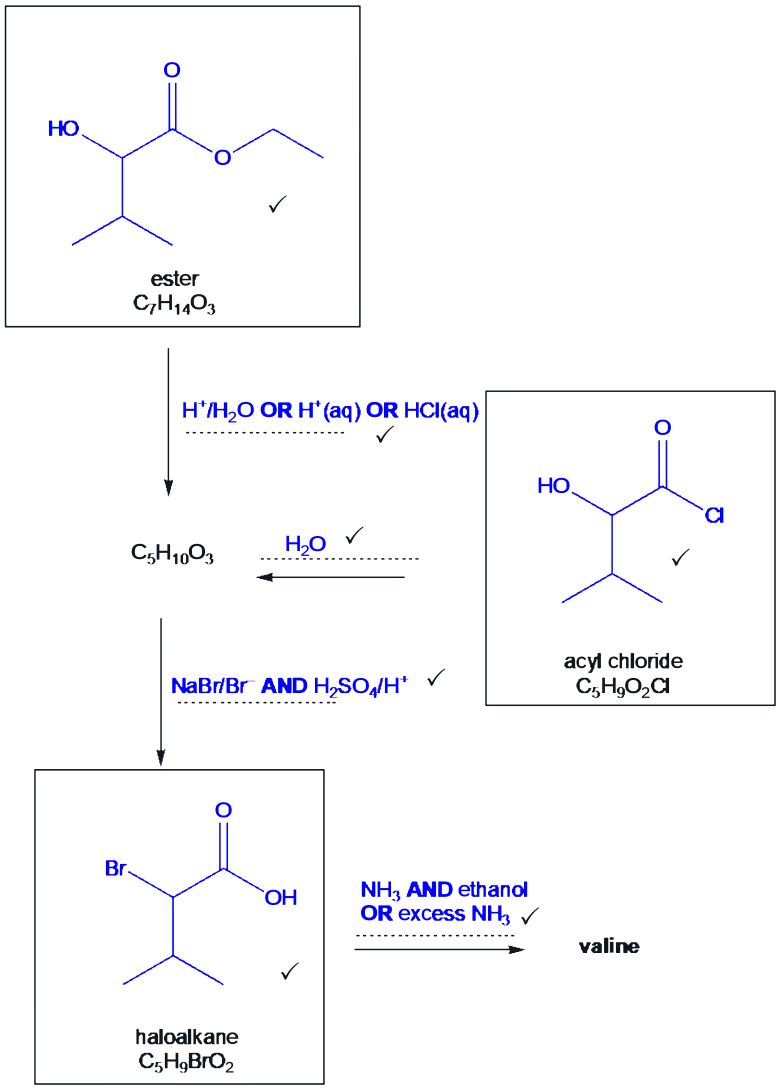
ALLOW *names of reagents*

DO NOT ALLOW *OH– for HO–*

but **ALLOW ECF** for subsequent use in (b)

For hydrolysis,

ALLOW *dilute acid*



ALLOW *alkaline conditions followed by protonation of carboxylate*

i.e. NaOH(aq)/OH^-(aq) **AND** H^+(aq)/HCl(aq)

ALLOW *HBr for NaBr/H_2SO_4*

[7 marks]

18(c)(i)

$C_{13}H_{18}O_2$ ✓

ALLOW *C, H and O in any order*

[1 mark]

18(c)(ii)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = 1.17×10^{21} award 3 marks

M(ibuprofen) = 206 ✓

$$n(\text{ibuprofen}) = \frac{\frac{400}{1000}}{206} = 1.94 \times 10^{-3} \text{ (mol)}$$ ✓

Number of molecules = $1.94 \times 10^{-3} \times 6.02 \times 10^{23}$

= 1.17×10^{21} to 3 SF ✓

ALLOW ECF *from (c)(i)*

Calculator: $1.941747573 \times 10^{-3}$

ALLOW ECF *from n(ibuprofen)*

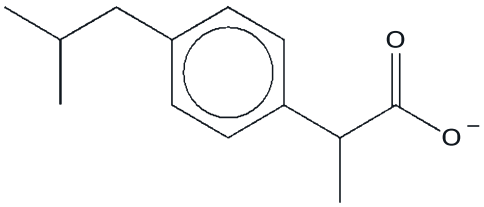
3 SF essential

[3 marks]

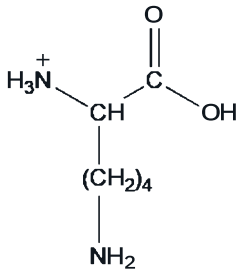
18(d)(i)

IGNORE *small slip in carbon chains*

ALLOW



✓



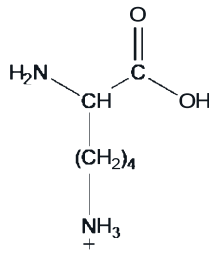
✓

[2 marks]

18(d)(ii)

More soluble in water ✓

[1 mark]



Answer must be a comparison

ALLOW *dissolve faster/quicker*

IGNORE *absorbed more quickly (given in question)*

Q17 · Amines, amino acids and polymers · [1 mark]

Answer: **B**

Optical isomerism only.

Q18 · Amines, amino acids and polymers · [1 mark]

Answer: **C**

$CH_3CH_2Cl \rightarrow CH_3CH_2NH_2$

Q19 · Aromatic compounds and phenols · [21 marks]

OCR MARK SCHEME

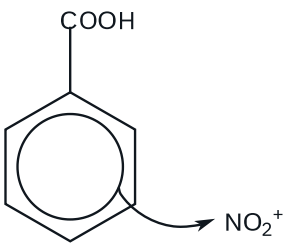
17(a)(i)

Generation of electrophile

$HNO_3 + H_2SO_4 \rightarrow H_2O + HSO_4^- + NO_2^+$ ✓

Electrophilic substitution

Curly arrow from π-bond to NO_2^+ ✓



EXAMINER GUIDANCE

ALLOW $HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + 2HSO_4^- + NO_2^+$

ALLOW $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$

then

$H_2NO_3^+ \rightarrow H_2O + NO_2^+$

ALLOW $^+NO_2$ ***OR*** NO_2^+

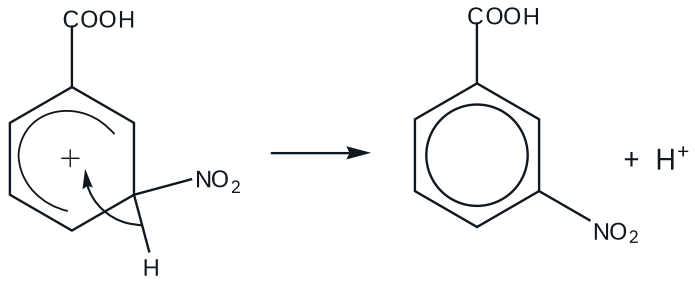
First curly arrow must come from the ring to NO_2^+

DO NOT ALLOW *the following intermediate:*

Correct intermediate ✓

Curly arrow back from C-H bond to reform π-ring

AND H^+ as product ✓



Regeneration of catalyst

$H^+ + HSO_4^- \rightarrow H_2SO_4$ ✓

[5 marks]

17(a)(ii)

Level 3 (5–6 marks)

Outlines the main steps of recrystallisation to produce a pure sample of 3-nitrobenzoic acid from the impure solid.

AND

Calculates correct percentage yield of 3-nitrobenzoic acid.

AND

Method of checking purity to include comparison to relevant data.

A well-structured response with the steps for recrystallisation and the determination of purity being given in the correct order. Correct use of terminology throughout.

Level 2 (3–4 marks)

Attempts all three scientific points but explanations may be incomplete.

OR

Explains two scientific points thoroughly with very few omissions.

The description of checking for purity or recrystallisation is clear and any calculations structured. Key terminology used appropriately.

Level 1 (1–2 marks)

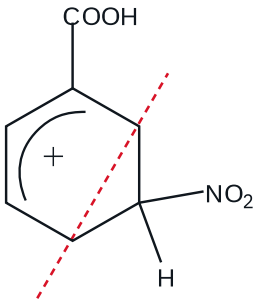
A simple explanation based on at least two of the main scientific points.

OR

Explains one scientific point thoroughly with few omissions.

There is an attempt at a logical structure. The description of the practical techniques provides some detail but may not be in the correct order.

- Purification step is unclear with few scientific terms and little detail, e.g. just 'recrystallise'.
- Calculation is difficult to follow, may just include a calculation of moles of reactants and/or products.



π-ring should cover approximately 4 of the 6 sides of the benzene ring structure

AND

the correct orientation, i.e. gap towards C with NO_2

ALLOW *+ sign anywhere inside the 'hexagon' of intermediate*

Indicative scientific points, with bulleted elements, may include:

1. Purification

- Recrystallisation
- Dissolve impure solid in minimum volume of hot water/solvent
- Cool solution and filter solid
- Wash with cold water/solvent and dry

2. Percentage yield

- *n*(benzoic acid) used $= \frac{4.97}{122} = 0.0407$ (mol)
- *n*(3-nitrobenzoic acid) made $= \frac{4.85}{167} = 0.0290$ (mol)
- percentage yield $= \frac{0.0290}{0.0407} \times 100 = 71.3$ (%)

ALLOW *71 to calculator value of 71.29001554 correctly rounded.*

CHECK for extent of errors by **ECF**

Alternative correct calculation may calculate theoretical mass of 3-nitrobenzoic acid that can be produced as $0.0407 \times 167 = 6.80$ (g) followed by:

percentage yield $= \frac{4.85}{6.80} \times 100 = 71.3$ (%)

- Purity check specifies a method but this is unclear with little detail, e.g. take melting point.

0 marks

No response or no response worthy of credit.

[6 marks]

Calculation must attempt to calculate *n*(benzoic acid) in mol.

3. Checking purity

- Obtain melting point
- Compare to known values
- Pure sample will have a (sharp) melting point very close to data book value

***ALLOW** alternative approach based on spectroscopy or TLC*

Spectroscopy

- Run an NMR/IR spectrum
- Compare to (spectral) database
- Spectrum of pure sample will contain same peaks and not others

TLC

- Run a TLC
- Compare (R_f value) to known data
- Pure sample will have a very similar R_f

17(b)(i)

Phenol is the most easily nitrated/ most reactive

AND

Benzoic acid is the least easily nitrated /least reactive ✓

[1 mark]

Response must give rank order of reactivity

e.g. nitration becomes more difficult from phenol (to benzene) to benzoic acid

OR

nitration becomes easier from right to left in the table

17(b)(ii)

Reactivity of phenol

a (lone) pair of electrons on O is (partially) delocalised/donated into the π-system / ring ✓

Reactivity of benzoic acid

The –COOH group on benzoic acid is an electron withdrawing group ✓

Links electron density in π-bond to reactivity

In phenol electron density is higher

AND

The ring is more susceptible to attack

OR

In benzoic acid electron density is lower

AND

The ring is less susceptible to attack ✓

[3 marks]

***ALLOW** the electron pair in the p orbitals of the O atom becomes part of the π-system / ring*

***ALLOW** diagram to show movement of lone pair into ring*

***ALLOW** lone pair of electrons on O is (partially) drawn/attracted/pulled into π-system / ring*

***IGNORE** activating and deactivating.*

***ALLOW** the following alternatives for susceptibility to attack:*

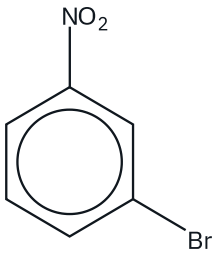
- phenol attracts electrophiles / NO_2^+ more
- phenol polarises electrophiles / NO_2^+ more

- benzoic acid attracts electrophiles / NO_2^+ less
- benzoic acid polarises electrophiles / NO_2^+ less

17(c)(i)

Bromination: Br_2 **AND** $AlBr_3/FeBr_3/Fe$ ✓

Intermediate



✓

Reduction: Sn **AND** (concentrated) HCl ✓

[3 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *any suitable halogen carrier catalyst*

ALLOW *Kekulé structure*

IGNORE *names (question asks for formulae)*

IGNORE *reaction conditions even if incorrect*

IGNORE *'dilute' for HCl*

IGNORE H_2

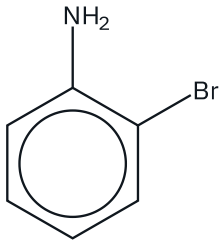
IGNORE *NaOH if seen as a reagent to convert nitro group into amine*

e.g 'Sn/(concentrated) HCl then NaOH' scores the mark

17(c)(ii)

NH_2 is 2,4 directing ✓

Products (1 mark for each):



✓



✓

IGNORE *references to electron donating/withdrawing groups*

ALLOW *–NH_2 activates the ring causing the new group to join at positions 2 and 4.*

ALLOW *ortho and para directing for 2,4 directing*

IGNORE *6-directing*

ALLOW *Kekulé structure*

IGNORE *names*

[3 marks]

Q20 · Aromatic compounds and phenols · [1 mark]

Answer: **C**

CH_3COCl

Q21 · Aromatic compounds and phenols · [1 mark]

Answer: **A**

1, 2 and 3

Q22 · Aromatic compounds and phenols · [9 marks]

OCR MARK SCHEME

18(a)(i)

Number of peaks 2 marks

2-nitrophenol **AND** 3-nitrophenol have six peaks/environments/types of carbon ✓

4-nitrophenol has four peaks/environments/types of carbon ✓

Statement 1 mark

4-nitrophenol can be distinguished

OR

2-nitrophenol and 3-nitrophenol cannot be distinguished ✓

[3 marks]

EXAMINER GUIDANCE

IGNORE *any numbers shown on structures*

ALLOW *1 mark only* ***IF*** *a response identifies that all the compounds have 6 peaks/environments/types of C*

OR all the compounds have 4 peaks/environments/ types of carbon

IGNORE *chemical shifts*

DO NOT ALLOW ECF *from an incorrect number of peaks/environments/types of carbon*

18(a)(ii)

(In phenol) a (lone) pair of electrons on O is(partially) delocalised/donated into the π-system / ring ✓

Electron density increases/is higher (than benzene) ✓

ORA

(phenol) is more susceptible to electrophilic attack

OR

(phenol) attracts/accepts electrophile/HNO_3 more

OR

(phenol) polarises electrophile/HNO_3 more ✓

ORA

[3 marks]

ALLOW *the electron pair in the p-orbitals of the O atom becomes part of the π-system / ring*

ALLOW *diagram to show movement of lone pair into ring*

ALLOW *lone pair of electrons on O is (partially) drawn/attracted/pulled/ into π-system / ring*

IGNORE *activating*

IGNORE *charge density*

IGNORE *electronegativity*

IGNORE *phenol reacts more readily (no reference to electrophile)*

ALLOW NO_2^+ *for electrophile*

18(b)

Curly arrow from π-bond to S in SO_3

AND

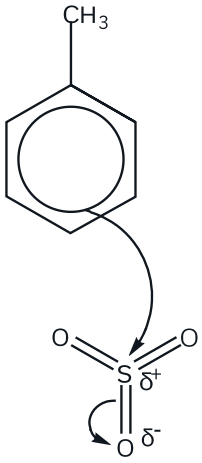
curly arrow from the S=O bond to O atom ✓

NOTE*: curly arrows can be straight, snake-like, etc. but* ***NOT*** *double headed or half headed arrows*

1st curly arrow must

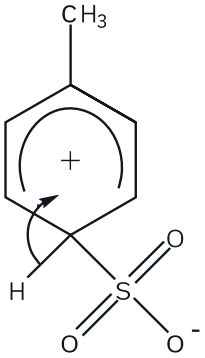
- go to the S of SO_3

AND



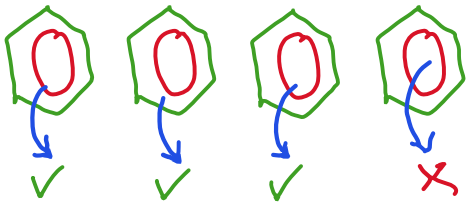
Correct intermediate ✓

Curly arrow from C-H bond to reform π-ring ✓

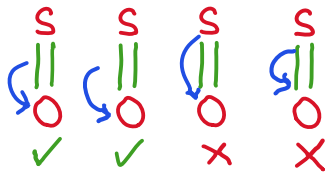


[3 marks]

- start from, **OR** close to circle of benzene ring



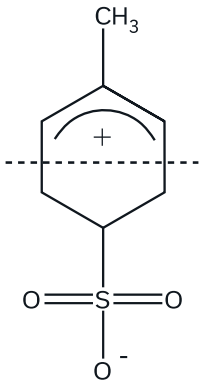
2nd curly arrow must start from, **OR** be traced back to, any part of S=O bond and go to O



ALLOW *2nd curly arrow from S=O to any O in* SO_3

Intermediate must have correct SO_3^- structure fully displayed

DO NOT ALLOW *the following intermediate:*



π-ring must cover more than half of the benzene ring structure

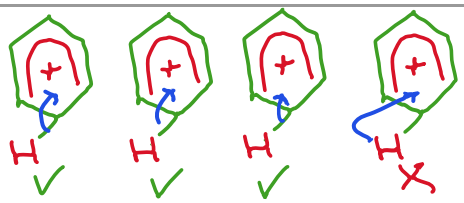
AND

the correct orientation, i.e. gap towards C with SO_3^-

ALLOW *+ sign anywhere inside the 'hexagon' of the intermediate.*

DO NOT ALLOW *mark for intermediate if* CH_3 *is missing*

curly arrow must start from, **OR** be traced back to, any part of C-H bond and go inside the 'hexagon'



Q23 · Aromatic compounds and phenols · [1 mark]

Answer: **A**

1, 2 and 3

Q24 · Aromatic compounds and phenols · [1 mark]

Answer: **C**

Q25 · Aromatic compounds and phenols · [22 marks]

OCR MARK SCHEME

20(a)(i)

Indicator **AND** observation of acidity

AND

No reaction with carbonate ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW (Add) bromine **AND** white precipitate ✓

ALLOW (Add) $FeCl_3$ **AND** violet/purple colour ✓

20(a)(ii)

Compound J has 6 peaks/environments/types of carbon ✓

Compound K has 5 peaks/environments/types of carbon ✓

Compound L has 8 peaks/environments/types of carbon ✓

[3 marks]

IGNORE *any numbers shown on structures*

IGNORE *chemical shifts*

20(a)(iii)

Action of catalyst 1 mark

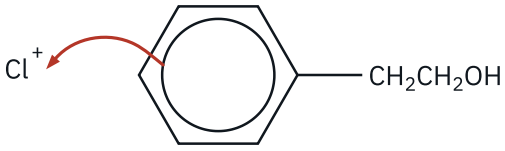
Formation of electrophile: $Cl_2 + AlCl_3 \rightarrow Cl^+ + AlCl_4^-$

AND

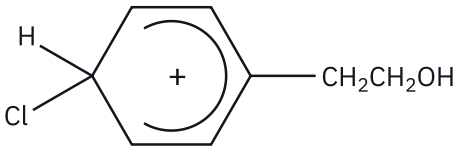
Regeneration of catalyst: $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓

Electrophilic attack 1 mark

Curly arrow from π-bond to Cl^+ ✓



Correct intermediate only 1 mark



ALLOW *use of $FeCl_3$ or other halogen carriers ($AlBr_3$)*

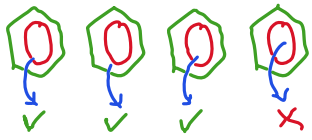
For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):

1st curly arrow must

- start from, **OR** close to circle of benzene ring

AND

- go to Cl^+

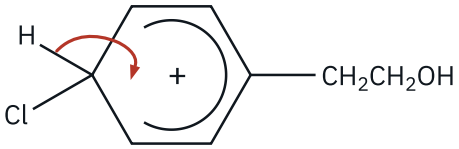


DO NOT ALLOW *the following intermediate:*

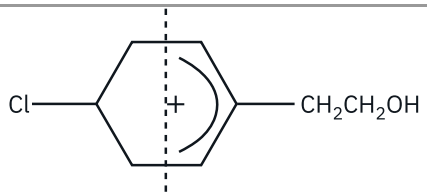
✓

Reforming benzene ring 1 mark

Curly arrow from C–H bond to reform π-ring ✓



[4 marks]



π-ring must cover more than half of benzene ring

AND

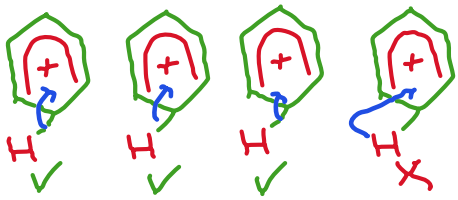
correct orientation, i.e. gap towards C with Cl

ALLOW *+ sign anywhere inside the 'hexagon' of intermediate*

DO NOT ALLOW *intermediates substituted at positions 3 or 5*

IGNORE *intermediates substituted at position 2* ***OR*** *di-substituted at positions 2,4*

Curly arrow must start from, **OR** be traced back to, any part of C–H bond and go inside the 'hexagon'



20(b)

(In phenols) a (lone) pair of electrons on O is (partially) delocalised/donated into the ring / π-system ✓

Electron density increases/is higher (than benzene) ✓

ORA

(phenols) are more susceptible to electrophilic attack

OR

(phenols) attract/accept electrophile/Cl_2 more

OR

(phenols) polarise electrophile/Cl_2 more ✓

ORA

[3 marks]

ALLOW *the electron pair in the p-orbitals of the O atom becomes part of the ring / π-system*

ALLOW *diagram to show movement of lone pair into ring*

ALLOW *lone pair of electrons on O is (partially) drawn/attracted/pulled/ into ring / π-system*

ALLOW *lone pair on O*

DO NOT ALLOW *(two) lone pairs are delocalised/donated into the ring / π-system*

IGNORE *activating*

IGNORE *charge density*

IGNORE *electronegativity*

IGNORE *phenols react more readily with electrophiles/Cl_2 (given in question)*

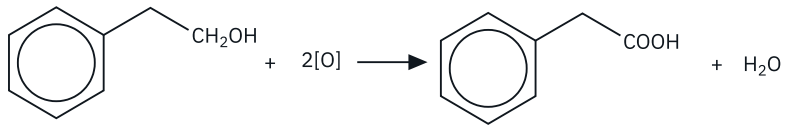
ALLOW *Cl^+ for electrophile*

IGNORE *Cl for electrophile*

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *C_6H_5 for phenyl group*

20(c)



organic product ✓

Correct balanced equation ✓

[2 marks]

IGNORE *references to concentration*

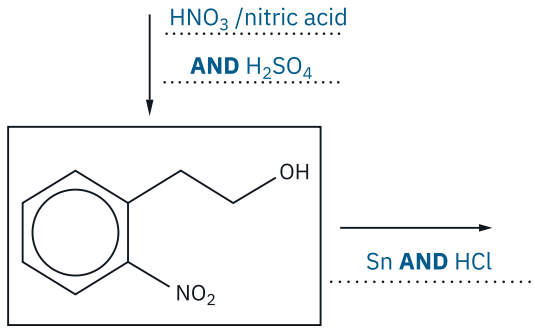
IGNORE *'dilute' for HCl*

IGNORE *H_2*

IGNORE *NaOH if seen as a reagent to convert nitro group into amine*

e.g 'Sn/(concentrated) HCl then NaOH' scores the mark

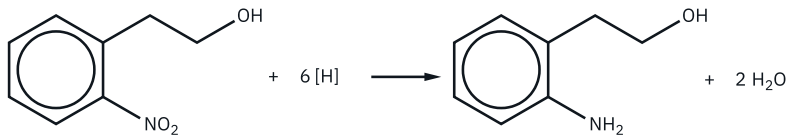
20(d)(i)



✓ ✓

[2 marks]

20(d)(ii)



✓

[1 mark]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *H^+* ***OR*** *HCl* ***OR*** *H_3PO_4*

DO NOT ALLOW *other named acids*

IGNORE *concentration/pressure*

IGNORE *water/steam*

For steam,

ALLOW *H_2O with temperature ≥100°C*

ALLOW *use of H_3PO_4/H_2SO_4 as catalyst*

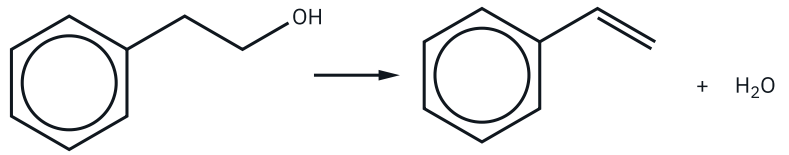
DO NOT ALLOW *HCl*

IGNORE *pressure*

20(e)

Stage 1

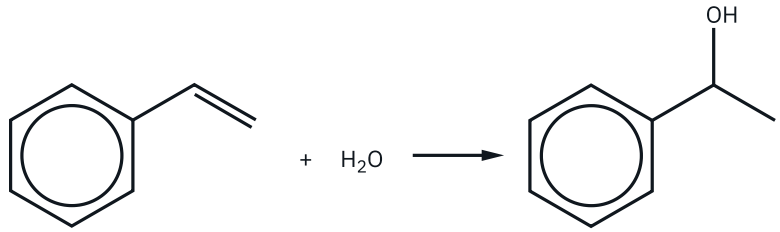
Reagents: H_2SO_4 ✓



✓

Stage 2

Reagents: Steam/H_2O(g) **AND** acid/H^+ (catalyst) ✓

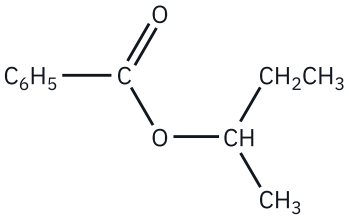


✓

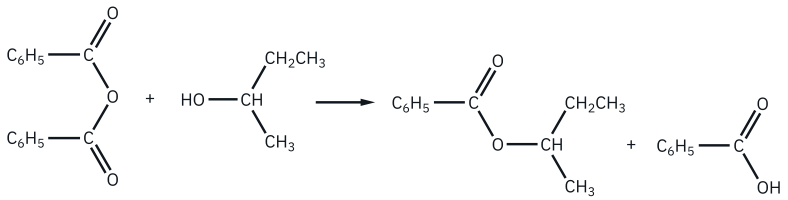
[4 marks]

20(f)

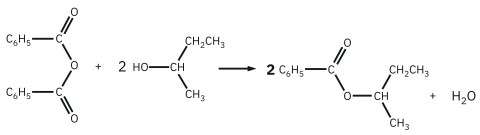
Structure of ester product ✓



Correct balanced equation ✓



[2 marks]

> ***ALLOW*** *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*
>
> ***ALLOW***
>
> 
>

Q26 · Aromatic compounds and phenols · [1 mark]

Answer: **D**

OCR MARK SCHEME

15

EXAMINER GUIDANCE

> ***ALLOW*** *15 (correct number of sigma bonds)*

Q27 · Aromatic compounds and phenols · [11 marks]

OCR MARK SCHEME

18(a)

Role of H_2SO_4 catalyst 2 marks

Forming electrophile

$HNO_3 + H_2SO_4 \longrightarrow H_2O + HSO_4^- + NO_2^+$ ✓

Reforming catalyst

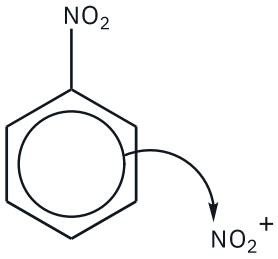
$H^+ + HSO_4^- \longrightarrow H_2SO_4$ ✓

Electrophilic attack 1 mark

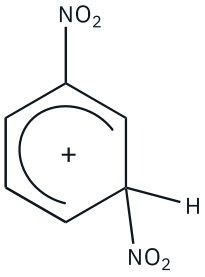
Curly arrow from π-bond to NO_2^+ ✓

EXAMINER GUIDANCE

> ***ALLOW***
>
> $HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + 2HSO_4^- + NO_2^+$
>
> ***ALLOW***
>
> $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$
>
> then $H_2NO_3^+ \rightarrow H_2O + NO_2^+$
>
> ***ALLOW*** $^+NO_2$ ***OR*** NO_2^+
>
> ***NOTE****: curly arrows can be straight, snake-like, etc.*



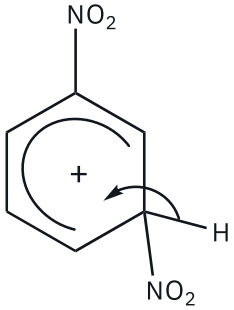
Correct intermediate 1 mark



✓

Reforming benzene ring 1 mark

Curly arrow from C–H bond to reform π-ring ✓



Curly arrow must start from, **OR** be traced back to, any part of C–H bond and go inside the 'hexagon'

[5 marks]

18(b)

FIRST CHECK ANSWER ON ANSWER LINE

If answer = 73.2 award 3 marks

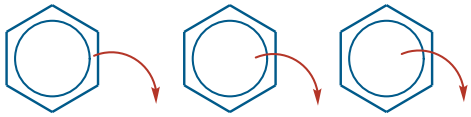
but **NOT** double headed or half headed arrows

1st curly arrow must

- start from, **OR** close to circle of benzene ring

AND

- go to anywhere on NO_2^+

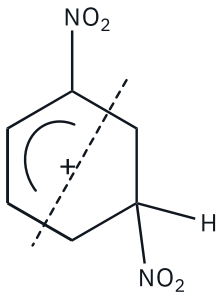


✓ ✓ ✗

DO NOT ALLOW *mark for intermediate if additional NO_2 is missing*

IGNORE connectivity to NO_2 groups (mark is for correct substitution position and position of π-ring)

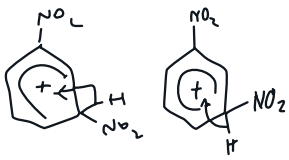
DO NOT ALLOW *the following intermediate:*



π-ring should cover approximately 4 of the 6 sides of the benzene ring structure

AND

the correct orientation, i.e. gap towards C with NO_2 and H



✓ ✗

ALLOW *+ sign anywhere inside the 'hexagon' of intermediate*

ALLOW *3SF up to calculator value throughout working*

IGNORE rounding errors past 3SF

Theoretical moles

$n(C_6H_5NO_2)$ **OR** $n(C_6H_4(NO_2)_2) = \frac{12.5 \times 1.20}{123.0}$ **OR** 0.12195... (mol) ✓

Actual moles

$n(C_6H_4(NO_2)_2) = \frac{15.0}{168.0}$ **OR** 0.0892857(mol) ✓

% yield = $\frac{0.0892857...}{0.12195....} \times 100 = 73.2$ % to 3SF ✓

[3 marks]

TAKE CARE as value written down may be truncated but with value stored in calculator, depending on rounding, either can be credited.

Calculator = 0.1219512195

Calculator = 0.08928571429

ALLOW ECF *except for final mark if value is ≥100%*

Alternative method using mass

1. Theoretical moles = 0.12195.... mol

2. Mass = 0.12195... × 168.0 **OR** 20.4878... g

3. % yield = $\frac{15}{20.4878...} \times 100 = 73.2\%$

Common errors

87.9% → 2 marks

- From $\frac{12.5}{123}$ = 0.101626.....(no density)

18(c)

Dissolve in the minimum quantity of hot water/solvent ✓

Cool (to allow crystals form)

AND

Then filter (under reduced pressure) ✓

(Leave to) dry ✓

[3 marks]

ALLOW *any solvent*

IGNORE

- Initial filtering
- Filtration between dissolving and cooling (implies hot filtration)
- Washing with cold solvent

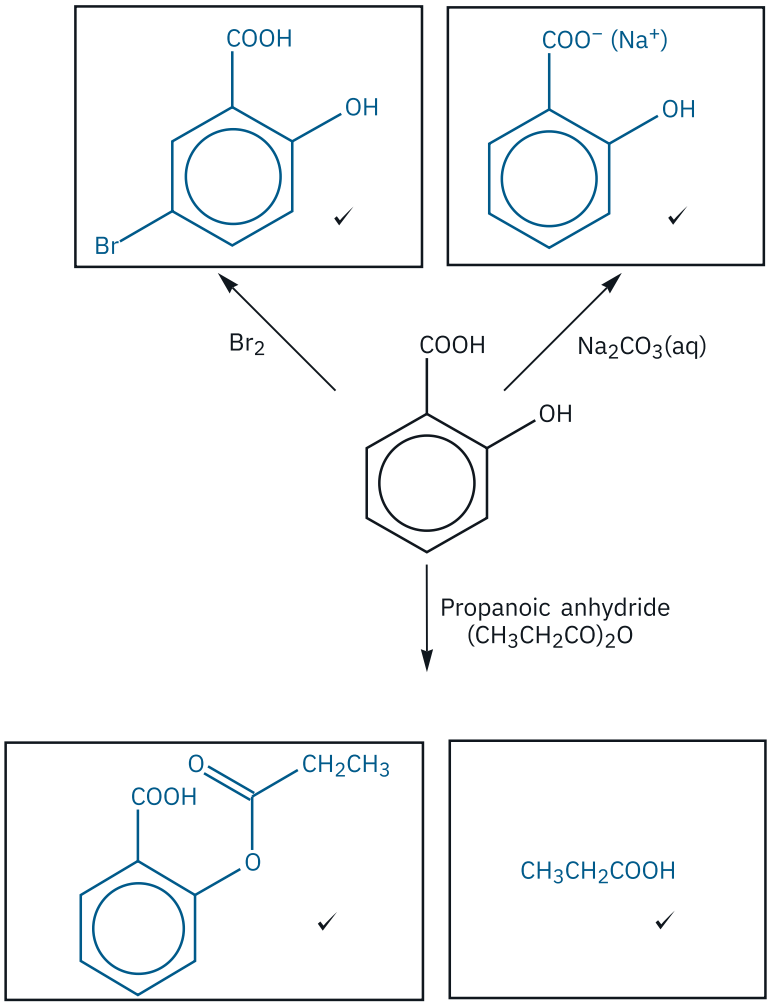
DO NOT ALLOW *use of drying agent (e.g. $MgSO_4$)*

Q28 · Aromatic compounds and phenols · [10 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

20(a)



IGNORE *connectivity of phenol OH group and COOH group throughout (marks are for correct conversions)*

Br_2

ALLOW *Br substitution at any position on ring*

ALLOW *up to 4 Br atoms onto ring*

Na_2CO_3

ALLOW *COO^-* ***OR*** *COONa*

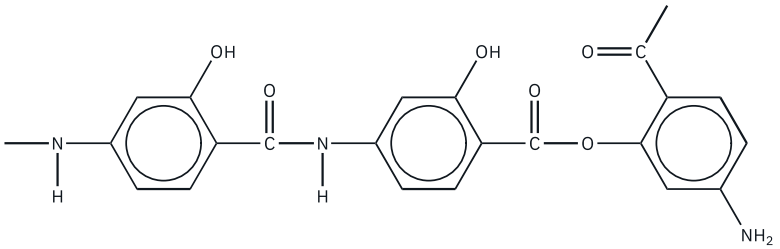
$(CH_3CH_2CO)_2O$

IGNORE *reaction of COOH to form an acid anhydride*

ALLOW *structures in bottom 2 boxes in either order*

[4 marks]

20(b)(i)



Section contains

A displayed amide linkage between 2 benzene rings ✓

A displayed ester linkage between 2 benzene rings ✓

Section with at least one 'end bond' and correct positioning of all 3 groups on each benzene ✓

Marking point 3 is dependent on first 2 marks

Check bonding around each benzene so C=O position 1, C-O position 2 and C-NH position 4.

ALLOW *'end bonds' (with either a solid or dashed line')* ***OR*** *terminal ends e.g. -O- or -OH*

ALLOW *any combination of 'end bonds' as showing a section not a repeat unit*

IGNORE *connectivity of OH and NH_2 groups to benzene*

[3 marks]

20(b)(ii)

FIRST CHECK ANSWER ON THE ANSWER LINE

If answer = 2.36×10^{22} award 3 marks

ALLOW *3SF up to calculator value throughout*

IGNORE *rounding errors past 3SF*

Calculate moles of PAS:

300 mg of PAS contains $\frac{300 \times 10^{-3}}{153}$ **OR** 1.96.... × 10^{-3} (mol) ✓

Daily dose of PAS:

n(PAS) for 20.0 kg child = 20 × 1.96.... × 10^{-3} (mol) **OR** 0.0392..... (mol) ✓

Use of Avogadro's constant:

Number of PAS molecules = 0.0392..... × 6.02 × 10^{23} = 2.36 × 10^{22} ✓

[3 marks]

*If there is an alternative answer, apply **ECF** throughout. Steps can be carried out in any order.*

Calculator values:

1.960784314 x 10^{-3}

0.03921568627

Common alternative method:

m(PAS) for 20.0 kg child = 0.3 x 20 **OR** 6.0 (g) ✓

n(PAS) for 20.0 kg child = $\frac{6}{153}$ **OR** 0.0392...(mol) ✓

Q29 · Aromatic compounds and phenols · [1 mark]

Answer: **C**

phenol, amide

Q30 · Aromatic compounds and phenols · [1 mark]

Answer: **B**

The carbon-carbon bond lengths are all the same.

Q31 · Aromatic compounds and phenols · [14 marks]

OCR MARK SCHEME

21(a)(i)

***ALLOW** correct Kekulé representation of benzene throughout question 21*

An electron pair acceptor ✓

[1 mark]

EXAMINER GUIDANCE

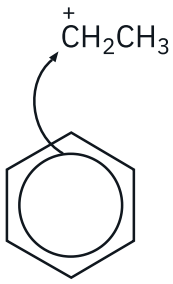
***ALLOW** gains an electron pair / lone pair*

21(a)(ii)

Generation of electrophile

$AlCl_3 + CH_3CH_2Cl \longrightarrow CH_3CH_2^+ + AlCl_4^-$ ✓

Electrophilic substitution



Curly arrow from π-bond to $^+CH_2CH_3$ ✓

***ALLOW** any combination of skeletal OR structural OR displayed formula as long as unambiguous*

***ALLOW** C_2H_5Cl AND $C_2H_5^+$*

***ALLOW** positive charge anywhere on CH_2CH_3 e.g. $CH_2CH_3^+$*

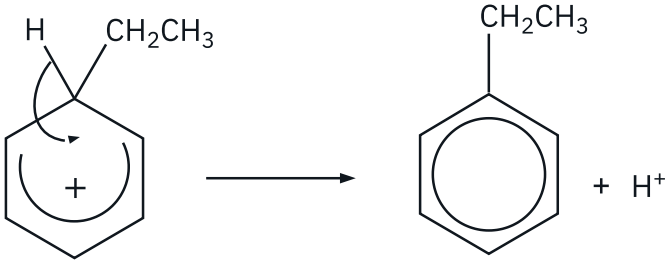
***NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows*

1st curly arrow must

- start from, OR close to circle of benzene ring

AND

- go to anywhere on $^+CH_2CH_3$



Correct intermediate ✓

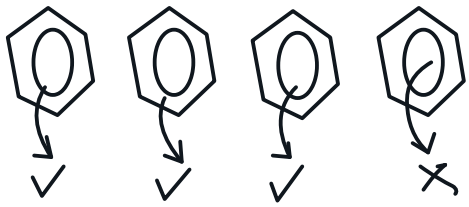
Curly arrow from C–H bond to reform π-ring

AND H^+ as product ✓

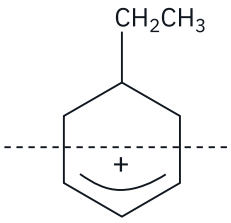
Regeneration of catalyst

$H^+ + AlCl_4^- \longrightarrow AlCl_3 + HCl$ ✓

[5 marks]



DO NOT ALLOW *the following intermediate:*



π-ring should cover approximately 4 of the 6 sides of the benzene ring structure

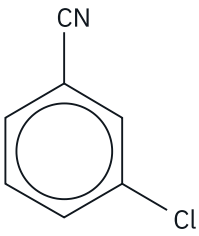
AND

'horseshoe' the right way,

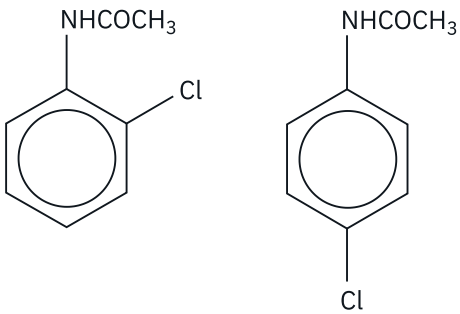
i.e. gap towards C with CH_2CH_3

ALLOW *+ sign anywhere inside the 'hexagon' of intermediate*

21(b)(i)



✓



✓ ✓

[3 marks]

IGNORE *additional copies of the same structures*

IGNORE *connectivity to CN and $NHCOCH_3$ in products.*

IGNORE *HCl / H^+*

IGNORE *multisubstituted products*

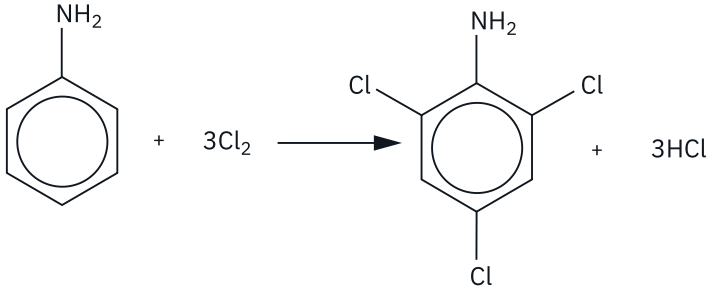
ALLOW *protonation of $NHCOCH_3$ group i.e. $NH_2^+COCH_3$*

ALLOW ECF *small slips on $NHCOCH_3$ e.g. extra O or missing 3 on CH_3*

21(b)(ii)

ALLOW *any trichlorophenyl amine structure*

ALLOW *$C_6H_2Cl_3NH_2$ OR $C_6H_4Cl_3N$ (allow elements in any order) for correct organic product*



Correct organic product ✓

Correct balanced equation ✓

[2 marks]

IGNORE *incorrect structural or molecular formula* ***IF*** *correct structure is drawn*

ALLOW *ammonium salt of trichloro product* $C_6H_2NH_3Cl_4$

ALLOW *multiples for balanced equation*

ALLOW *1 mark for use of* Br_2 *with a correctly balanced equation*

21(b)(iii)

(In phenylamine) a (lone) pair of electrons on N is (partially) delocalised / donated into the π-system / ring ✓

Electron density increases/is higher (than benzene) ✓

ORA

(phenylamine is) more susceptible to electrophilic attack

OR

(phenylamine) attracts/accepts electrophile/Cl_2 more

OR

(phenylamine) polarises electrophile/Cl_2 more ✓

ORA

[3 marks]

Must be clear that electrons come from N not just NH_2

ALLOW *the electron pair (in the p-orbitals) on N atom becomes part of the π-system / ring*

ALLOW *diagram to show movement of lone pair into ring from N*

ALLOW *lone pair of electrons on N is (partially) drawn / attracted / pulled into π-system / ring*

ALLOW *lone pair on N (i.e. no reference to electrons)*

ALLOW *π-bond instead of π-system / ring*

DO NOT ALLOW *(two) lone pairs are delocalised/donated into the π-system / ring*

Responses must be comparative for 2nd and 3rd marking point.

IGNORE *activating*

IGNORE *charge density*

IGNORE *electronegativity*

IGNORE *phenylamines react more readily with electrophiles/*Cl_2 *(given in question)*

ALLOW Cl^+ *for electrophile*

IGNORE *Cl for electrophile*

ALLOW *Benzene can't polarise electrophile/*Cl_2 *but phenylamine can (polarise electrophile/*Cl_2*)*

Q32 · Aromatic compounds and phenols · [16 marks]

OCR MARK SCHEME

4(a)(i)

In (Equilibrium) 1,

EXAMINER GUIDANCE

ALLOW *description for 1 or 2 as long as unambiguous, e.g. Equation 1, etc*

$H_2PO_4^-$/It acts as a base

AND

accepts/gains H^+/a proton

OR $H_2PO_4^-$ forms H_3PO_4 ✓

In (Equilibrium) 2

$H_2PO_4^-$/It acts as an acid,

AND

donates/loses H^+/a proton

OR $H_2PO_4^-$ forms HPO_4^{2-} ✓

[2 marks]

IGNORE *missing charge on $H_2PO_4^-$ throughout*

IGNORE *reference to HPO_4^{2-} acting as an acid/base* ***OR*** *Equilibrium 3*

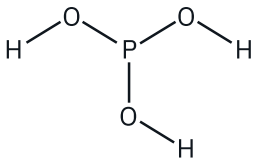
Question is about $H_2PO_4^-$

ALLOW *'dissociates into H^+ and HPO_4^{2-}'*

IGNORE *'partially'*

4(a)(ii)

Diagram showing all bonds correctly ✓



- 3 bonds only around each P
- 2 bonds only around each O
- Each O bonded to an H

Bond angles

O–P–O = 107° ✓

P–O–H = 104.5° ✓

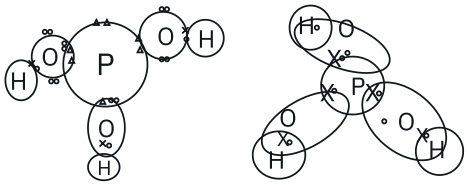
[3 marks]

IGNORE *geometry*

ALLOW *dot and cross diagram showing 2 shared electrons for each bond*

..... and **IGNORE** any lone pairs

e.g.



Unambiguous bond angles may be shown on dot and cross diagram

ALLOW *106–108°*

ALLOW *104–105°*

4(a)(iii)

phosphoric(III) acid ✓

Oxidation number MUST be in correct place

[1 mark]

DO NOT ALLOW *phosphoric acid (III)*

DO NOT ALLOW *phosphorous acid*

4(b)(i)

$4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓

[1 mark]

ALLOW *multiples*

ALLOW *$2PH_3 + 4O_2 \rightarrow P_2O_5 + 3H_2O$*

IGNORE *state symbols, even if wrong*

4(b)(ii)

$6AgNO_3 + (1)PH_3 + 3H_2O \rightarrow 6Ag + (1)H_3PO_3 + 6HNO_3$ ✓

Ag is reduced from +1 to 0 ✓

P is oxidised from –3 to +3 ✓

IGNORE *oxidation numbers written around equation*

Treat as rough working

IGNORE *reference to electrons*

Question states oxidation numbers

ALLOW *equation with '1' omitted, i.e.*

$6AgNO_3 + PH_3 + 3H_2O \rightarrow 6Ag + H_3PO_3 + 6HNO_3$ ✓

BUT **DO NOT ALLOW** '0'

ALLOW *1 mark for BOTH correct oxidation number changes with 'reduced' and 'oxidised' omitted*

[3 marks]

4(c)(i)

$3PCl_5 + 3NH_4Cl \rightarrow P_3N_3Cl_6 + 12HCl$ ✓

[1 mark]

4(c)(ii)

FIRST, CHECK THE ANSWER ON ANSWER LINE

IF *% by mass = 26.72, award 2 marks*

IF *% by mass = 26.7, award 1 mark*

M_r of $P_3N_3Cl_6$ = 348(.0) ✓

% by mass of P = $\frac{31.0 \times 3}{348} \times 100 = 26.72$ ✓

2 DP required

[2 marks]

4(c)(iii)

(P–N) bond lengths are different ✓

OR

enthalpy change of hydrogenation is more exothermic (than delocalised structure)

OR

reacts with bromine/electrophiles/by addition

[1 mark]

4(c)(iv)

Structure shown with molecular formula $P_3N_3Cl_6$

1st mark

- Each P bonded to 2 Cl atoms
- Each P bonded to N **AND** Cl
- Each N has at least 2 bonds
- Each Cl has 1 bond ✓

2nd mark (dependent on 1st mark)

- Each N has 3 bonds
- Each P has 3 **OR** 5 bonds ✓

IGNORE *charges*

Examples for 2 marks

OR 'oxidised and reduced the wrong way round

+ signs required for +1 and +3

For oxidation numbers,

ALLOW *1+, 3– and 3+*

ALLOW *multiples*

IGNORE *state symbols, even if wrong*

ALLOW *1 mark total for 26.7*

Question asks for 2 DP

ALLOW ECF *from incorrect* M_r

ALLOW *1 mark for 8.91 (omission of ×3):*

$\frac{31.0}{348} \times 100 = 8.91$

Throughout, **ORA** for delocalised structure

IGNORE *C–C bond lengths are different*

IGNORE *hydration*

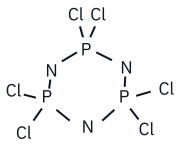
ALLOW *decolourises bromine (without a catalyst/halogen carrier)*

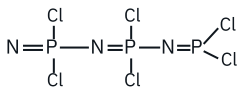
IGNORE *more reactive without example*

IGNORE *alternating single and double bonds*

1st mark

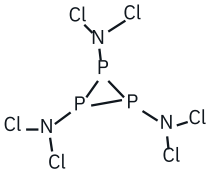
Meets criteria for 1st mark

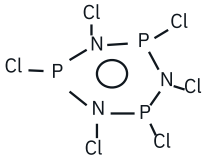




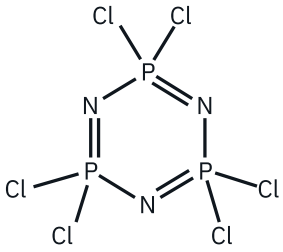
ZERO marks

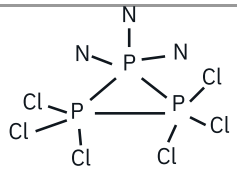
N bonded to Cl

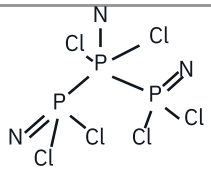


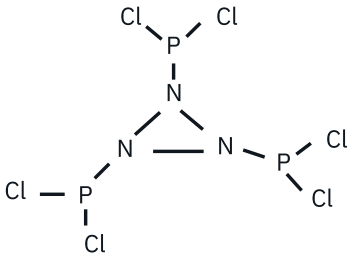


N atom(s) with 1 bond only

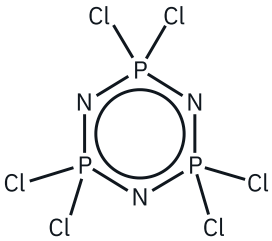








✓✓ BOD



[2 marks]

Q33 · Aromatic compounds and phenols · [17 marks]

OCR MARK SCHEME

20(a)

(In the delocalised model):

(C–C) bond length is between single (C–C) and double bond (C=C)

OR all (C–C) bond lengths are the same ✓

(Enthalpy change of) hydrogenation is less exothermic (than expected) ✓

[2 marks]

EXAMINER GUIDANCE

IGNORE *less susceptible to electrophilic attack (given in question)*

DO NOT ALLOW *enthalpy of hydration* ***OR*** $\Delta_{hyd}H$

ALLOW *'less negative'* ***OR*** *'more positive'* ***OR*** *'less (heat) energy released' for 'less exothermic'* ***IGNORE*** *higher/lower*

ALLOW *comparison of values that show delocalised is less exothermic e.g. Kekulé is -360 delocalised is -208*

20(b)(i)

(In phenol) a (lone) pair of electrons on O is (partially) delocalised/donated into the ring / π-system ✓

Electron density increases/is higher (than benzene) ✓

ORA

(phenol is) more susceptible to electrophilic attack

OR

(phenol can) attract/accept electrophile/Br_2 more

OR

ALLOW *the electron pair in a p-orbital on O atom becomes part of the ring / π-system*

ALLOW *diagram to show movement of lone pair into ring*

ALLOW *lone pair of electrons on O is (partially) drawn/attracted/pulled/ into ring / π-system*

ALLOW *lone pair on O*

DO NOT ALLOW *(two) lone pairs are (partially) delocalised into ring / π-system*

(phenol can) polarise electrophile/Br_2 more ✓

ORA

[3 marks]

Responses must be comparative for 2nd and 3rd marking point

IGNORE *activating*

IGNORE *charge density*

IGNORE *electronegativity*

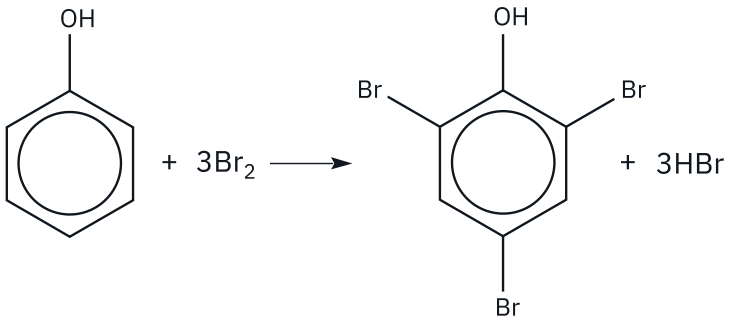
ALLOW *Br^+ for electrophile*

IGNORE *Br for electrophile*

ALLOW *Benzene can't polarise electrophile/Br_2 but phenol can (polarise electrophile/Br_2)* ***ORA***

IGNORE *phenol reacts more readily/easily with electrophiles*

20(b)(ii)



2,4,6-tribromophenol product ✓

Rest of equation and balancing ✓

[2 marks]

ALLOW *Kekulé structure*

DO NOT ALLOW *substitution at any three positions on ring, must be 2, 4, 6.*

IGNORE *molecular formula even if incorrect*

DO NOT ALLOW ECF *for organic product with incorrect number of substituted Br*

(Second mark is dependent on getting first mark)

20(c)(i)

CH_3Cl **AND** $AlCl_3$ ✓

[1 mark]

ALLOW *names if no formulae given*

ALLOW *CH_3Br for reagent*

ALLOW *$AlBr_3$* ***OR*** *$FeCl_3$* ***OR*** *$FeBr_3$ for the Lewis acid*

ALLOW *suitable non-specification alternative Lewis acids e.g. zeolite, BF_3*

20(c)(ii)

Role of H_2SO_4 catalyst 2 marks

Forming electrophile

$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$ ✓

Reforming catalyst

$H^+ + HSO_4^- \rightarrow H_2SO_4$ ✓

Electrophilic attack 1 mark

Curly arrow from π-bond to NO_2^+ ✓

ALLOW *for forming an electrophile*

$HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$

ALLOW *for forming an electrophile*

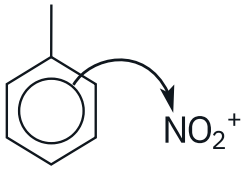
$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$

AND then $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$

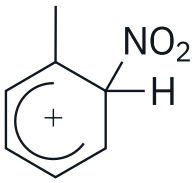
NOTE*: curly arrows can be straight, snake-like etc. but* ***NOT*** *double headed or half headed arrows*

ALLOW *use of $^+NO_2$* ***OR*** *NO_2^+*

1st curly arrow must:



Correct intermediate 1 mark

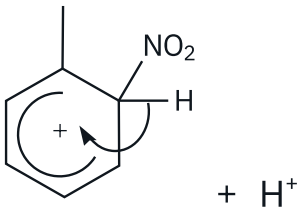


✓

Reforming benzene ring 1 mark

Curly arrow from C–H bond to reform π-ring

AND H^+ as product ✓

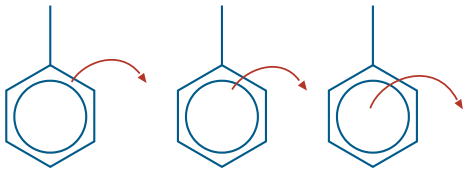


[5 marks]

- start from, **OR** close to circle or benzene ring

AND

- go to anywhere on NO_2^+

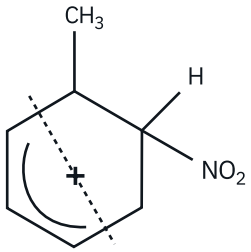


✓ ✓ ✗

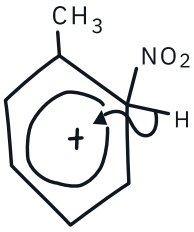
DO NOT ALLOW *mark for intermediate if methyl group is missing, or substitution is in wrong position*

IGNORE *connectivity (mark is for correct substitution position and position of π-ring)*

DO NOT ALLOW *following intermediates:*



OR



✗

π -ring should cover approximately 4 of the 6 sides of the benzene ring structure

AND

the correct orientation, i.e. gap towards C with NO_2 and H

ALLOW *+ sign anywhere inside the 'hexagon' of intermediate*

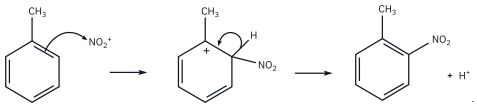
2nd curly arrow must:

- start from, **OR** be traced back to any part of the C – H bond

AND

- go inside the 'hexagon' of the intermediate

ALLOW *mechanism using Kekulé structures with wheland intermediate*

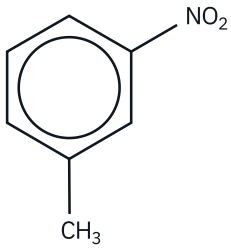


20(c)(iii)

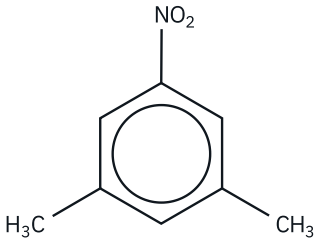
(Synthesis 1 shows that the) $-CH_3$ is 2, (4)-directing

AND

(Synthesis 2 is not successful because) $-NO_2$ / nitro group is 3-directing ✓



OR



✓

ALLOW *CH_3 is 2, (4)-directing* ***AND*** *$-NO_2$ / nitro group is not (2, 4-directing)*

ALLOW *$-NO_2$ / nitro group is 3-directing AND $-CH_3$ is not*

IGNORE *CH_3 and NO_2 have different directing effects (the directing effect of at least one of the groups must be specified)*

ALLOW *alternatives for 'directing' e.g. substitutes at*

ALLOW *$-NO_2$ / nitro group is meta directing*

ALLOW *$-CH_3$ is ortho, (para) directing*

IGNORE *5-directing for $-NO_2$*

IGNORE *6-directing for $-CH_3$*

ALLOW *Kekulé structure*

[2 marks]

20(c)(iv)

Reagents

Sn **AND** HCl ✓

Equation



H_2O product **AND** balancing ✓

ALLOW *names if no formulae given*

IGNORE *dilute for HCl*

IGNORE *H_2 (with Sn and HCl)*

IGNORE *NaOH if seen as a reagent to convert nitro group into amine*

e.g 'Sn/(concentrated) HCl then NaOH' scores the mark

ALLOW *suitable non-specification alternatives:*

e.g. Zn **AND** HCl

OR H_2 **AND** Ni

[2 marks]

Q34 · Aromatic compounds and phenols · [1 mark]

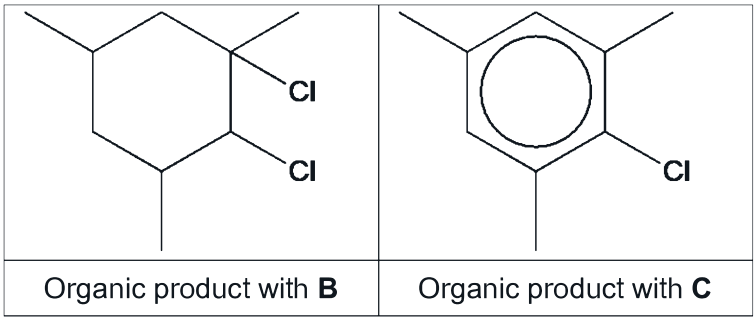
Answer: **C**

Only 2 and 3

Q35 · Aromatic compounds and phenols · [20 marks]

OCR MARK SCHEME

17(a)(i)



✓✓

[2 marks]

17(a)(ii)

Reactivity of B

in B electrons are localised

OR

in B π-bond is localised ✓

Reactivity of C

in C electrons are delocalised

OR

In C π-system / ring is delocalised

In B, electron density is higher

AND

B is more susceptible to electrophilic attack

OR

B attracts/accepts the electrophile/Cl_2 more

OR

B polarises the electrophile/Cl_2 more ✓

ORA

[3 marks]

17(a)(iii)

Generation of electrophile

$AlCl_3 + Cl_2 \rightarrow AlCl_4^- + Cl^+$ ✓

Attack of Cl^+

EXAMINER GUIDANCE

ALLOW *labelled diagram to show delocalised system*

IGNORE *charge density*

IGNORE *electronegativity*

IGNORE *B is more reactive/reacts more readily (no reference to electrophile)*

IGNORE *references to electron density spread around the π–ring*

ALLOW *chlorine*

ALLOW *$FeCl_3 + Cl_2 \rightarrow FeCl_4^- + Cl^+$*

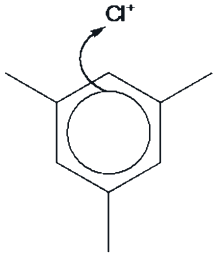
ALLOW *use of Fe*

NOTE*: curly arrows can be straight, snake-like, etc.*

..... but **NOT** double-headed or half-headed arrows

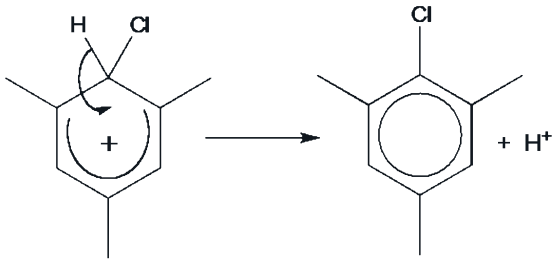
1st curly arrow must

- start from, **OR** close to, circle of benzene ring



Curly arrow from π-bond to Cl^+ ✓

Intermediate and organic product



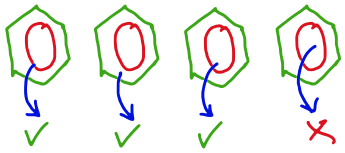
Correct intermediate ✓

Curly arrow from C–H bond to reform π-ring ✓

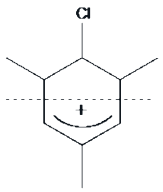
Regeneration of catalyst

$H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓

[5 marks]



DO NOT ALLOW *following intermediate:*



π-ring must cover 4 of the 6 sides of the benzene ring

AND

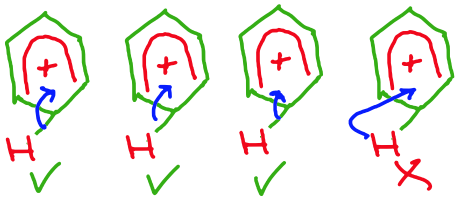
correct orientation, i.e. gap towards C–Cl

ALLOW *+ sign anywhere inside the 'hexagon' of the intermediate.*

IGNORE *partial charges on the chlorine in the intermediate*

DO NOT ALLOW *mark for intermediate if any CH_3 is missing*

Curly arrow must start from, **OR** be traced back to, any part of C–H bond and go inside the 'hexagon'



ALLOW *use of $AlCl_4^-$ in the mechanism*

ALLOW *ECF for regeneration of an incorrect metal chloride catalyst e.g. $AgCl_3$*

17(b)

$3C_3H_6O \rightarrow C_9H_{12} + 3H_2O$

molecular formulae of C_3H_6O **AND** C_9H_{12} ✓

H_2O as by-product ✓

correct balanced equation ✓

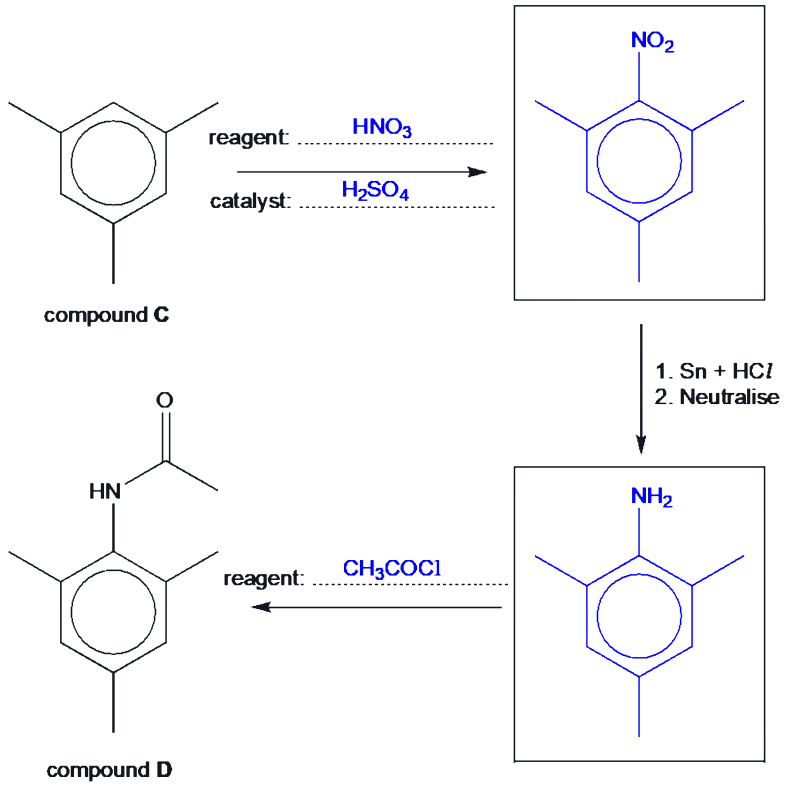
[3 marks]

17(c)(i)

	Compound C	Compound D
Number of peaks	3 ✓	8 ✓

[2 marks]

17(c)(ii)



✓✓✓✓✓

[5 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

IGNORE *names for organic intermediates (question asks for structures*

ALLOW *names of reagents and catalyst*

Around top arrow, **ALLOW** 1 of 2 marks if HNO_3 and H_2SO_4 swapped.

i.e.

reagent: H_2SO_4

catalyst: HNO_3

IGNORE *references to concentration*

ALLOW *$(CH_3CO)_2O$ for left arrow*

IGNORE *CH_3COOH*

IGNORE *acyl chloride*

DO NOT ALLOW *$AlCl_3/FeCl_3/Fe_4$*

Q36 · Aromatic compounds and phenols · [1 mark]

Answer: **A**

Aqueous potassium hydroxide

Q37 · Aromatic compounds and phenols · [1 mark]

Answer: **C**

Only 2 and 3

Q38 · Aromatic compounds and phenols · [1 mark]

Answer: **A**

1, 2 and 3

Q39 · Aromatic compounds and phenols · [20 marks]

OCR MARK SCHEME

20(a)(i)

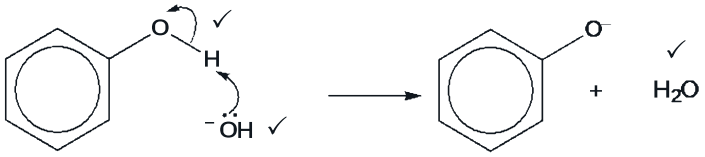
Stage 1

EXAMINER GUIDANCE

NOTE*: curly arrows can be straight, snake-like, etc.*

but **NOT** double headed or half headed arrows

Curly arrow from OH^- must



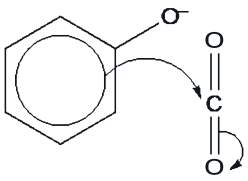
1 mark for each curly arrow as shown.

Stage 2

Curly arrow from π-ring to C in CO_2

AND

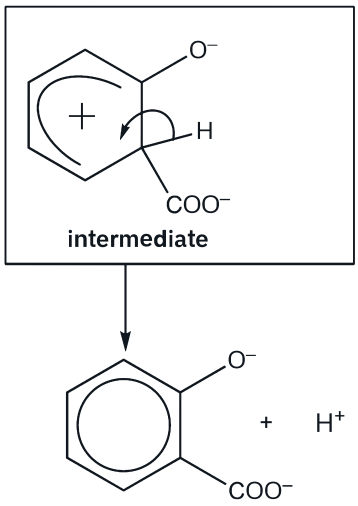
curly arrow from the C=O bond to O atom ✓



Correct intermediate ✓

Curly arrow from C–H bond to reform π-ring

AND H^+ formed ✓

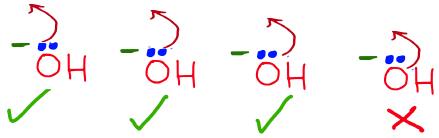


[6 marks]

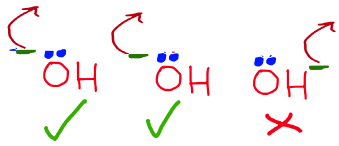
- go to the H of O–H

AND

- start from, **OR** be traced back to any point across width of lone pair on O of OH^-



- **OR** start from – charge⁻OH ion



Curly arrow from O–H bond must start from, **OR** be traced back to, any part of O–H bond and go to O

IGNORE *dipoles on O-H bond*

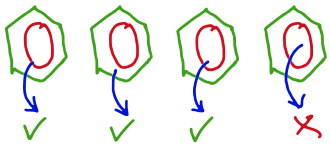
IGNORE *Na^+*

1st curly arrow must

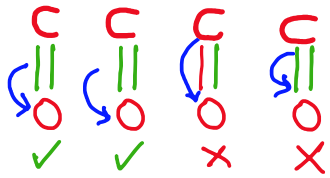
- go to the C of CO_2

AND

- start from, **OR** close to circle of benzene ring

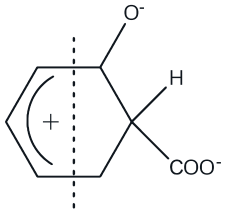


2nd curly arrow must start from, **OR** be traced back to, any part of C=O bond and go to O



ALLOW 2nd *curly arrow from C=O to any O in CO_2*

DO NOT ALLOW *the following intermediate:*



π-ring must cover more than half of the benzene ring structure

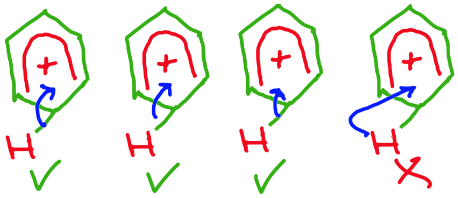
AND

the correct orientation, i.e. gap towards C with CO_2^-

ALLOW *+ sign anywhere inside the 'hexagon' of the intermediate.*

DO NOT ALLOW *mark for intermediate if phenolic O^- is missing*

curly arrow must start from, **OR** be traced back to, any part of C-H bond and go inside the 'hexagon'



20(a)(ii)

OH^- : base ✓

CO_2: electrophile **OR** electron pair acceptor ✓

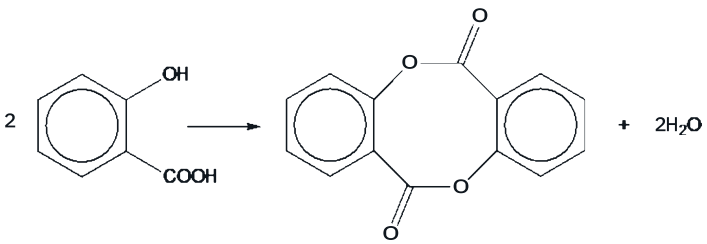
[2 marks]

ALLOW *alkali*

IGNORE *'nucleophile', 'donates electron pair'*

IGNORE *lone pair acceptor (No lone pair involved)*

20(a)(iii)



One ester link in organic product ✓

Correct structure of organic product ✓

Correct equation **AND** balanced ✓

[3 marks]

20(b)(i)

Dissolve in hot water/solvent ✓

Minimum amount of solvent ✓

ALLOW *any solvent*

IGNORE

- Initial filtering

Cool **AND** Filter **AND** (leave to) dry ✓

All three needed

[3 marks]

- hot filtration to remove insoluble impurities

DO NOT ALLOW *adding of a drying agent (e.g. $MgSO_4$)*

20(b)(ii)

C : H : N : O

$$\frac{31.44}{12} : \frac{1.31}{1} : \frac{18.34}{14} : \frac{48.91}{16}$$

OR 2.62 : 1.31 : 1.31 : 3.06 ✓

6:3:3:7

OR

$C_6H_3N_3O_7$ ✓

Molecular formula = $C_6H_3N_3O_7$

AND use of M = 229.0 (directly linked to molecular formula) ✓

Any trisubstituted $–NO_2$ substituted phenol that is consistent with M = 229.0 ✓

Evidence for substitution

2,4,6 **OR** 3,4,5 substituted phenol

AND 4 peaks/ C environments from ^{13}C NMR ✓

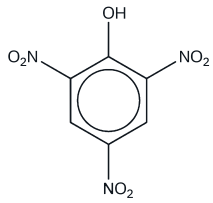
2,4,6 substituted phenol

AND directing effects of –OH ✓

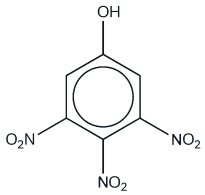
[6 marks]

ALLOW *alternative approach for empirical formula and evidence that 229 is equal to $C_6H_3N_3O_7$*

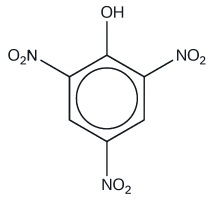
DO NOT ALLOW *ECF from the empirical formula with the wrong molar ratio*



2,4,6



3,4,5



2,4,6

Q40 · Carbon–carbon bond formation and synthesis · [1 mark]

Answer: **B**

Only 1 and 2

Q41 · Carbon–carbon bond formation and synthesis · [1 mark]

Answer: **B**

Only 1 and 2

Q42 · Carbon–carbon bond formation and synthesis · [11 marks]

OCR MARK SCHEME

4(a)(i)

+2

Sign required

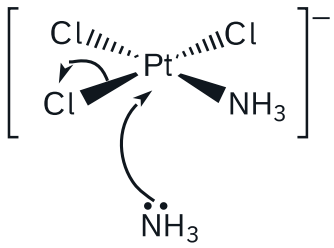
[1 mark]

EXAMINER GUIDANCE

ALLOW *2+* ***OR*** *+II*

ALLOW *Pt^{2+}*

4(a)(ii)



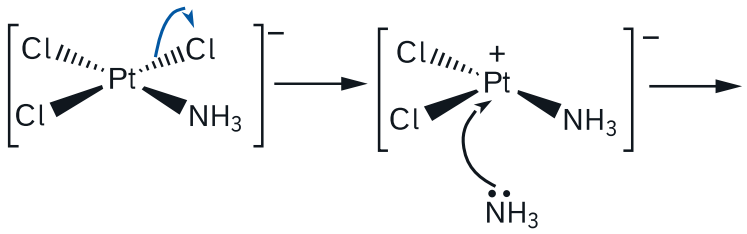
Curly arrow from lone pair on NH_3 to Pt ✓

$[PtCl_3(NH_3)]^-$ drawn with 1 Pt, 3 Cls and 1 NH_3

AND

Curly arrow from **any** Pt–Cl bond in the complex ✓

ALLOW *S_N1 mechanism:*



Mark curly arrows as above for S_N2

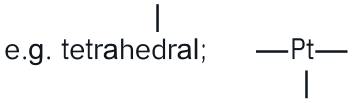
Requires + on platinum intermediate

[2 marks]

For $[PtCl_3(NH_3)]^-$:

- **IGNORE** dipoles
- **IGNORE** absence of – charge
- **IGNORE** – charge shown on atoms

ALLOW *any 4 coordinate shape for $[PtCl_3(NH_3)]^-$,*

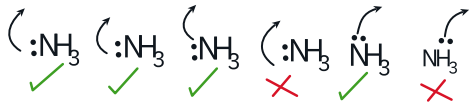


1st curly arrow must

- go to Pt

AND

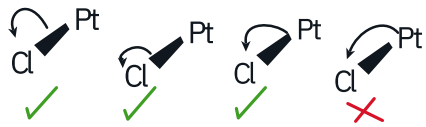
start from, **OR** be traced back to **any point across width** of lone pair on N of NH_3



DO NOT ALLOW *charge on NH_3 nucleophile,*

e.g. NH_3^-

2nd curly arrow must start from, **OR** be traced back to, **any part of** Pt–Cl bond and go to one of the 3 Cl atoms



4(b)(i)

Phenol ✓

Amide ✓

- **IGNORE** attempt to classify amide, e.g. secondary

[2 marks]

IF > 2 *functional groups are shown,*

- Mark 2 groups **ONLY**
- Mark incorrect groups **first**

Treat carbonyl with aldehyde **OR** with ketone as one functional group,

i.e.

- carbonyl, aldehyde

- carbonyl, ketone
- carbonyl

IGNORE *aryl* ***OR*** *alkyl group*

e.g. benzene, phenyl, aryl, arene, methyl

IGNORE *hydroxyl/hydroxy*

4(b)(ii)

Level 3 (5-6 marks)

A correct calculation of the mass of 4-nitrophenol.

AND

Identifies the reagents **AND** intermediate.

AND

A **detailed** description of most purification steps.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3-4 marks)

Calculates the mass of 4-nitrophenol with some errors **AND** suggests reagents and intermediate with some omissions.

OR

Calculates the mass of 4-nitrophenol with some errors **AND** describes some purification steps, with some detail.

OR

Suggests reagents and intermediate with some omissions **AND** describes some purification steps, with some detail.

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1-2 marks)

Attempts to calculate the mass of 4-nitrophenol

OR

Suggests reagents **OR** intermediate but may be incomplete

OR

Describes few purification steps.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks *No response or no response worthy of credit.*

[6 marks]

Indicative scientific points may include:

Calculation of mass of 4-nitrophenol

Using moles

- n(paracetamol) $= \frac{5.00}{151} = 0.0331$ (mol)
- n(4-nitrophenol) $= \frac{0.0331 \times 100}{40} = 0.0828$ (mol)
- Mass of 4-nitrophenol = 139 × 0.0828 = 11.5 g

ALLOW *11.4–11.6 for small slip/rounding*

Using mass

- Theoretical mass paracetamol $= \frac{5.00 \times 100}{40} = 12.5$ g
- Theoretical n(4-nitrophenol) $= \frac{12.5}{151} = 0.0828$ (mol)
- Mass of 4-nitrophenol = 139 × 0.0828 = **11.5** g

NOTE*: Incorrect inverse ratio of 100 / 40 gives:*

- $\frac{0.0331 \times 40}{100} = 0.0132$ (mol)
- Mass = 139 × 0.0132 = 1.84 g

Reagents and intermediate

- **Reagents:** Sn + (conc) HCl (then NaOH)
- **Intermediate**: 4-aminophenol or structure

Purification

- Dissolve impure solid in **minimum volume of** hot solvent
- **Cool** solution and filter solid
- **Scratch with glass rod**

- **Wash** with cold solvent/solvent and **dry**

Examples of detail in **bold (NOT INCLUSIVE)**

***NOTE**: 'Recrystallisation' on its own is **NOT** a detailed description*

Q43 · Carbon–carbon bond formation and synthesis · [6 marks]

OCR MARK SCHEME

21

Level 3 (5–6 marks)

Describes, in detail, reactions of two aliphatic compounds that form a C–C bond

AND mechanisms for the two aliphatic reactions.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Describes a reaction of one aliphatic compound that forms a C–C bond with few omissions/errors.

AND mechanism for one aliphatic reaction.

OR

Describes reactions of two compounds that forms a C–C bond

AND attempts a mechanism for one of the reactions

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Selects suitable reagents for reactions of two compounds that form a C–C bond.

OR

Attempts to describe a reaction and mechanism of one compound that forms a C–C bond, with omissions/errors.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks No response or no response worthy of credit.

[6 marks]

EXAMINER GUIDANCE

Indicative scientific points may include:

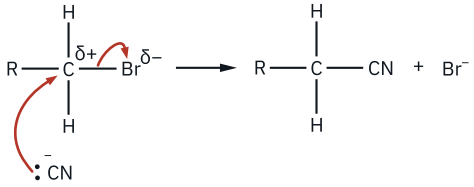
Reactions of aliphatic compounds and mechanisms

- Haloalkane, RX and CN^- → RCN + X^-

Reagents: NaCN and ethanol

Reaction: Nucleophilic substitution

Mechanism:



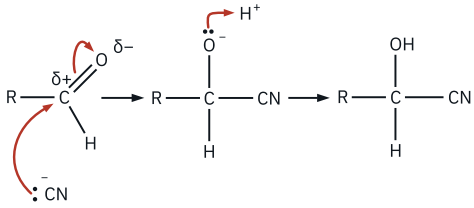
- Aldehyde or ketone and HCN

e.g. RCHO + HCN → RCH(OH)CN

Reagents: NaCN and H^+

Reaction: Nucleophilic addition

Mechanism:



OR H_2O instead of H^+ for 2nd stage

Q44 · Carbon–carbon bond formation and synthesis · [14 marks]

OCR MARK SCHEME

19(a)(i)

3-methylbut-2-enal ✓

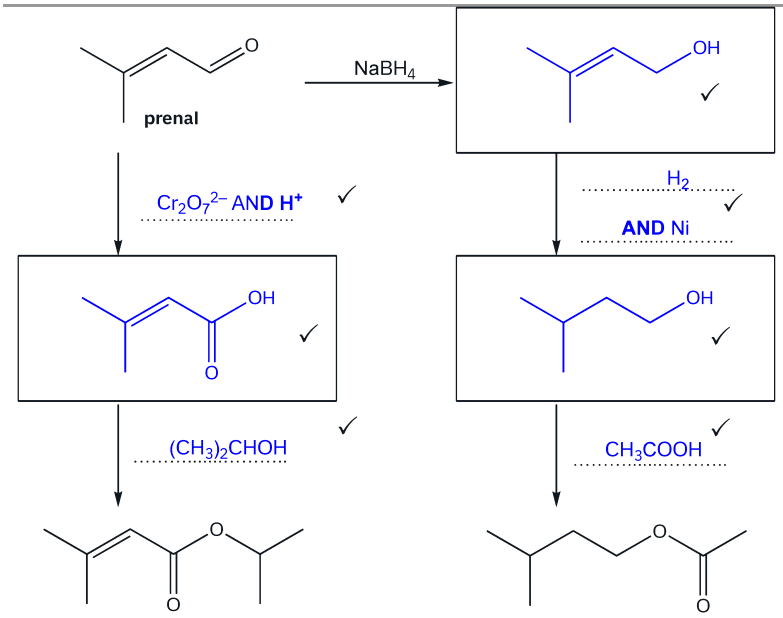
[1 mark]

EXAMINER GUIDANCE

***IGNORE** lack of hyphens, or addition of commas*

19(a)(ii)

ALLOW** any combination of skeletal **OR



*structural **OR** displayed formula as long as unambiguous*

***ALLOW** names of reagents and catalyst*

For oxidation,

***ALLOW** $K_2Cr_2O_7$ for $Cr_2O_7^{2-}$*

***ALLOW** H_2SO_4 for H^+*

For left hand side esterification

***IGNORE** C_3H_7OH*

[7 marks]

19(b)

Level 3 (5-6 marks)

Correct calculation of the mass of $C_6H_5CH_2Cl$

AND

Planned synthesis to form the intermediate $C_6H_5CH_2CN$ followed by hydrolysis to form A with most of the reagents identified and equations are mostly correct.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3-4 marks)

Correct calculation of the mass of $C_6H_5CH_2Cl$

AND

Planned synthesis to form the intermediate $C_6H_5CH_2CN$ with most of the reagents identified and equation is mostly correct

OR

Calculation of the mass of $C_6H_5CH_2Cl$ is partly correct

AND

Planned synthesis includes formation of the intermediate $C_6H_5CH_2CN$ followed by hydrolysis to form A with some of the reagents identified

OR

Attempts to calculate mass of $C_6H_5CH_2Cl$ but makes little progress

AND

Planned synthesis includes formation of the intermediate $C_6H_5CH_2CN$ followed by hydrolysis to form A with most of the reagents identified and equations are mostly correct

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Indicative scientific points may include:

Calculation of mass of $C_6H_5CH_2Cl$

Using moles

- $n(A) = \frac{5.44}{136} = 0.04(00)$ (mol)
- $n(C_6H_5CH_2Cl) = \frac{0.0400 \times 100}{25} = 0.16(0)$ (mol)
- Mass of $C_6H_5CH_2Cl = 126.5 \times 0.16 = 20.2(4)$ g

Using mass

- Theoretical mass of ester $= \frac{5.44 \times 100}{25} = 21.76$ (g)
- Theoretical $n(C_6H_5CH_2Cl) = \frac{21.76}{136} = 0.16(0)$ (mol)
- Mass of $C_6H_5CH_2Cl = 126.5 \times 0.160 = 20.2(4)$ g

***ALLOW** small slip/rounding errors such as errors in M_r e.g. use of 137 instead of 136 for $C_6H_5CH_2COOH$*

Examples of partly correct calculations

Mass = 1.265 g from $\frac{0.0400 \times 25}{100} \times 126.5$

(% yield inverted)

Level 1 (1-2 marks)

Calculation of the mass of $C_6H_5CH_2Cl$ is partly correct

OR

Attempts to calculate mass of $C_6H_5CH_2Cl$ but makes little progress

AND

Planned synthesis includes formation of the intermediate $C_6H_5CH_2CN$ with the reagent identified

OR

Planned synthesis includes both steps with some of the reagents identified

OR

Attempts equations for both steps but these may contain errors

OR

Describes one step of the synthesis with reagent(s) and equation mostly correct

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

[6 marks]

Mass = 5.06 g from 0.0400 × 126.5

(% yield omitted)

Synthesis: reagents and conditions

Stage 1: Formation of intermediate, $C_6H_5CH_2CN$

- Reagents: CN^-(/ethanol)
- Equation:

$C_6H_5CH_2Cl + CN^- \rightarrow C_6H_5CH_2CN + Cl^-$

OR $C_6H_5CH_2Cl + NaCN \rightarrow C_6H_5CH_2CN + NaCl$

(**OR** use of KCN)

Stage 2: Formation of A, $C_6H_5CH_2COOH$

- Reagents: H^+/H_2O (**ALLOW** 'acid hydrolysis'
- Equation:

$C_6H_5CH_2CN + 2H_2O + H^+ \rightarrow C_6H_5CH_2COOH + NH_4^+$

OR $C_6H_5CH_2CN + 2H_2O + HCl \rightarrow C_6H_5CH_2COOH + NH_4Cl$

Q45 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **D**

CH_3COCl

Q46 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **A**

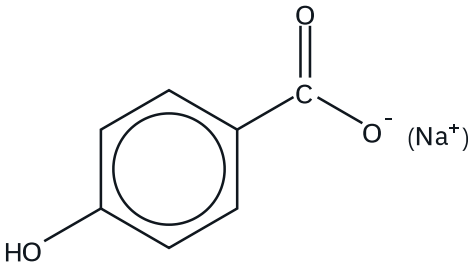
$CH_3CH_2COCl + CH_3NH_2$

Q47 · Carbonyls, carboxylic acids and esters · [12 marks]

OCR MARK SCHEME

21(a)

Product from Na_2CO_3



✓

EXAMINER GUIDANCE

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *–COO⁻* ***OR*** *–COONa*

DO NOT ALLOW *negative charge on C atom*

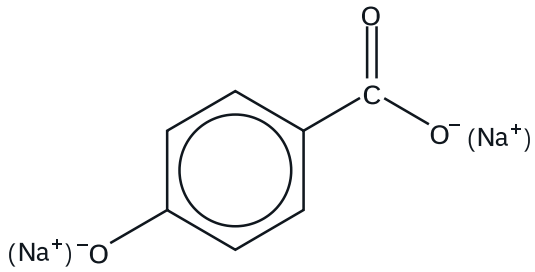
DO NOT ALLOW *–COO–Na (covalent bond)*

IGNORE *connectivity of phenol OH group*

(marks are for correct conversions)

ALLOW *1 mark if top two structures are shown in wrong boxes*

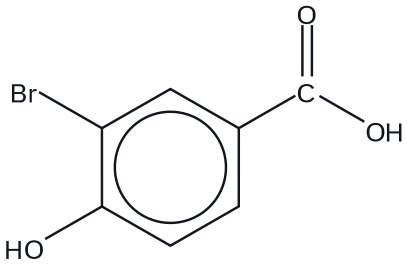
Product from NaOH(aq)



✓

Product from Br_2

e.g.



✓

[3 marks]

ALLOW *substitution of any H from benzene ring*

ALLOW *multiple substitution, i.e. di-, tri- and tetrabromo products.*

IGNORE *connectivity of phenol OH group*

(marks are for correct conversions)

21(b)

One mark for each correct structure/reagent as shown below

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *PCl_5* ***OR*** *PCl_3 for reagent mark.*

IGNORE *references to temperature for reagent mark*

IGNORE *additional reagents shown with $SOCl_2$/PCl_5/PCl_3 e.g. H_2O, $AlCl_3$, HCl etc.*

IGNORE *names (question asks for structures of organic compounds and formula of reagent)*

DO NOT ALLOW *more than two repeat units*

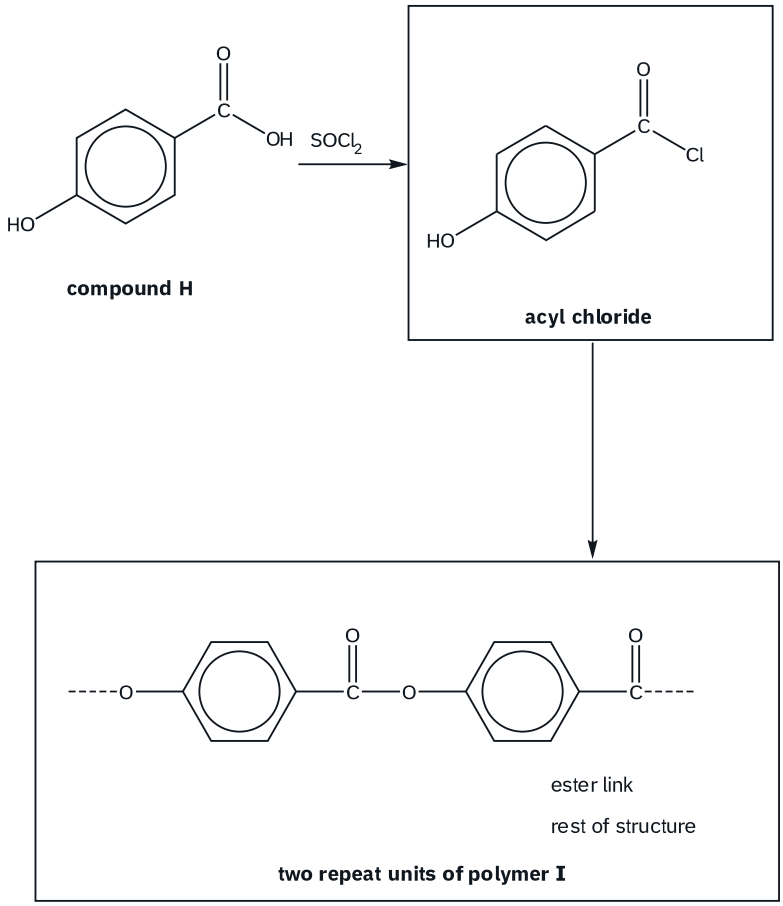
ALLOW *1 mark for one correct repeat unit*

e.g.



'End bonds' MUST be shown (do not have to be dotted)

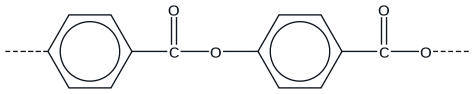
ALLOW *the 'O' at either end*



✓✓✓✓

[4 marks]

i.e.



IGNORE *brackets*

IGNORE *n*

21(c)(i)

FIRST CHECK ANSWER ON ANSWER LINE

IF answer = 7.5 × 10^{-4} award 2 marks

[K] in mol dm^{-3}

$\frac{9.13 \times 10^{-2}}{166} = 5.50 \times 10^{-4}$ (mol dm^{-3}) ✓

[L] from peak areas

$\frac{5.50 \times 10^{-4} \times 5.9}{4.3}$ **OR** $5.50 \times 10^{-4} \times 1.37$.....

$= 7.5 \times 10^{-4}$ (mol dm^{-3}) ✓

2 SF Required

[2 marks]

If there is an alternative answer, ***Apply ECF***

Alternative method

[K] in g dm^{-3} with peak area of 5.9

$\frac{9.13 \times 10^{-2} \times 5.9}{4.3}$ **OR** $9.13 \times 10^{-2} \times 1.37$

= 0.125 **OR** 0.13 (g dm^{-3}) ✓

Calculator: 0.125272093

[L] in mol dm^{-3}

$\frac{0.125}{166} = 7.5 \times 10^{-4}$

OR $\frac{0.13}{166} = 7.8 \times 10^{-4}$ (mol dm^{-3}) ✓

Common errors:

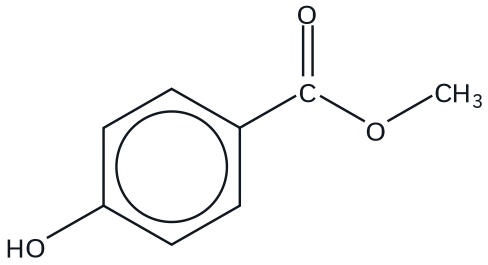
Award 1 mark for:

- 0.099 (from $\frac{9.13 \times 10^{-2}}{166} \times 180$)
- 6.9×10^{-4} (from $\frac{0.125}{180}$)

- 7.2×10^{-4} (from $\frac{0.13}{180}$)
- 7.0×10^{-4} (from $\frac{0.25272093}{180}$)

21(c)(ii)

ester J



✓

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

L and M can be identified either way round

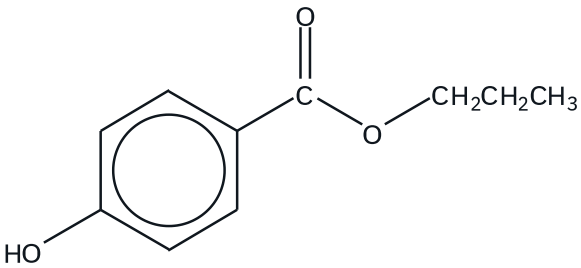
IGNORE *'C_3H_7' in L and/or M as ambiguous*

(question requires structures)

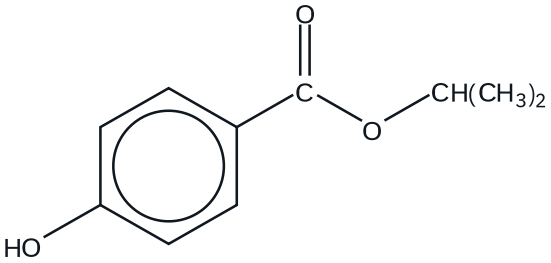
IGNORE *connectivity of phenol OH group*

(marks are for structures of alkyl groups)

esters L and M



✓



✓

[3 marks]

Q48 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **C**

Only 2 and 3

Q49 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **B**

Only 1 and 2

Q50 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **B**

$C_3H_5O_2Na$

Q51 · Carbonyls, carboxylic acids and esters · [12 marks]

OCR MARK SCHEME

18(a)(i)

(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate ✓

Take melting point (of crystals) ✓

Compare to known values/database ✓

[3 marks]

EXAMINER GUIDANCE

ALLOW *errors in spelling*

ALLOW *2,4(-)DNP* ***OR*** *2,4(-)DNPH*

ALLOW *Brady's reagent or Brady's Test*

ALLOW *solid* ***OR*** *crystals* ***OR*** *ppt as alternatives for precipitate*

Mark second and third points independently of response for first marking point

DO NOT ALLOW *2nd and 3rd marks for taking and comparing boiling points* ***OR*** *chromatograms*

18(a)(ii)

Tollens' (reagent)

AND

Silver (mirror/precipitate/ppt/solid) ✓

[1 mark]

ALLOW *ammoniacal silver nitrate* ***OR*** Ag^+/NH_3

ALLOW *black ppt* ***OR*** *grey ppt*

ALLOW $Cr_2O_7^{2-}/H^+$

AND

Turns green ✓

IGNORE *reference to conditions,*

e.g. Heat or reflux

18(b)

Initial ratios

C, $\frac{62.07}{12.0}$: H, $\frac{10.34}{1.0}$: O, $\frac{27.59}{16.0}$

OR

C, 5.1725 : H, 10.34 : O, 1.724

OR

C, 3 : H, 6 : O, 1 ✓

(Molecular formula =) C_3H_6O

AND

Evidence of 58 in working or from labelled peak in one of the spectra ✓

For F

evidence for fragment ion m/z=29 linked to $CH_3CH_2^{(+)}$ **OR** $CHO^{(+)}$ ✓

CHECK spectra for annotations that may be worthy of credit

Mark can be awarded from a correct molecular formula

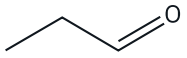
IGNORE *m/z=15 (as this is not unique)*

IGNORE *m/z=43*

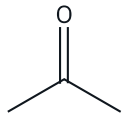
IGNORE *incorrect fragments*

IGNORE *charges on fragment ions*

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

F = 

AND

G = 

✓

[4 marks]

18(c)

^{1}H NMR

δ = 1.1 ppm/doublet linked to 2 x CH_3 ✓

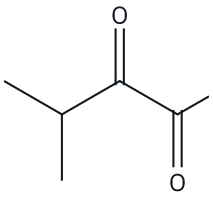
δ = 2.2 ppm/singlet linked to CH_3–C=O

OR

δ = 2.9 ppm/multiplet linked to C**H**$(CH_3)_2$ **OR H**C–C=O ✓

Structure

Any structure with molecular formula $C_6H_{10}O_2$ and has 2 carbonyl groups ✓



✓

[4 marks]

***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

CHECK spectra for annotations that may be worthy of credit

***ALLOW** δ values ± 0.2 ppm, as a range or a value within the range*

***IGNORE H**C–C=O linked to δ = 2.2 ppm*

***IGNORE** additional chemical environments (taken from the data sheet) that align with the given chemical shifts*

Q52 · Carbonyls, carboxylic acids and esters · [22 marks]

OCR MARK SCHEME

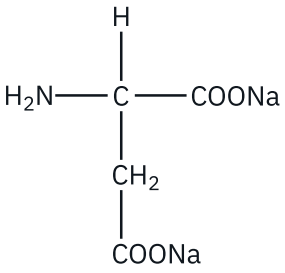
19(a)

$C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓

$2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓

H_2O **AND** CO_2 ✓

Correct formula of salt:



✓

[4 marks]

EXAMINER GUIDANCE

***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

***IGNORE** state symbols and use of equilibrium sign*

***ALLOW** KC_2H_5COO*

***DO NOT ALLOW** a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but*

***IGNORE** for next equations.*

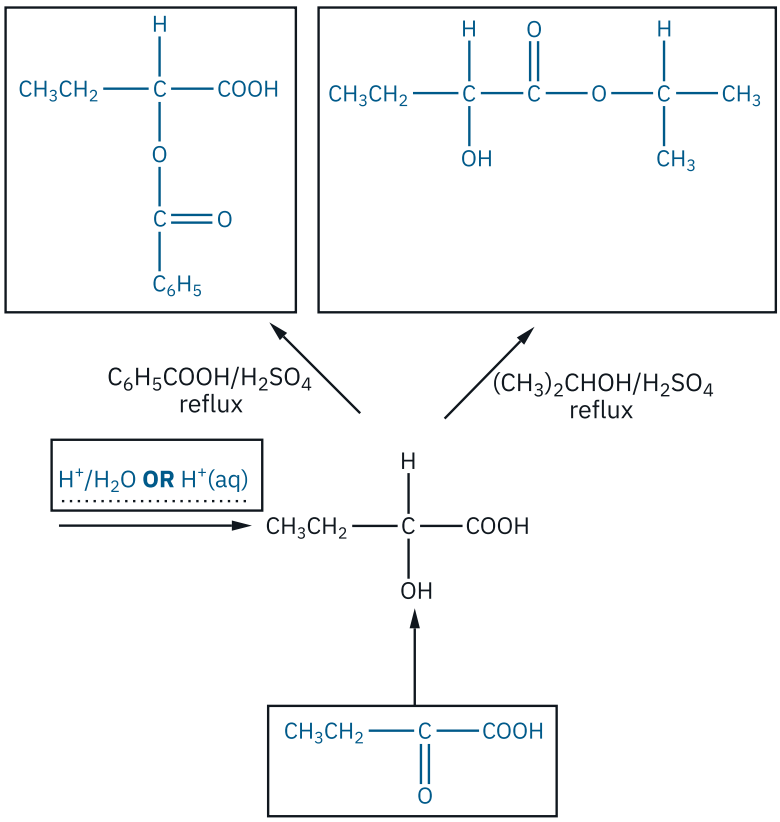
For salts,

***ALLOW** $C_2H_5COO^-K^+$ **OR** $C_2H_5COO^- + K^+$*

***DO NOT ALLOW** –COO–K (covalent bond) the 1st time seen but **IGNORE** for next equations.*

FOR $CO_2 + H_2O$ **ALLOW** H_2CO_3

19(b)



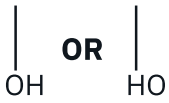
✓ ✓ ✓ ✓

[4 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *any vertical bond to the OH group*

e.g. **ALLOW**



IGNORE *connectivity of CH_3CH_2 group*

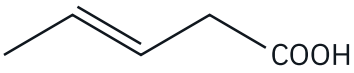
IGNORE *inorganic by-products*

ALLOW *HCl/H_2O, H_2SO_4/H_2O*

IGNORE *dilute*

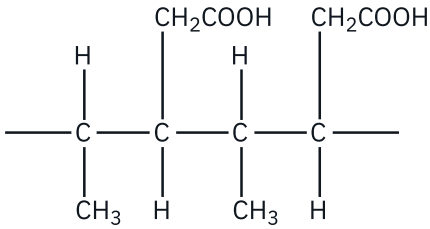
19(c)(i)

Pent-3-enoic acid



✓

2 repeat units of polymer



✓

[2 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *either the E or Z isomer*

ALLOW ECF *from pent-2-enoic acid*

OR pent-4-enoic acid ONLY

For repeat unit,

- 'side bonds' required on either side of repeat unit from C atoms
- 2 repeat units required

IGNORE *connectivity of CH_2COOH in polymer*

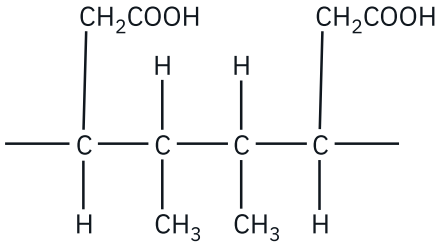
IGNORE *brackets*

IGNORE *n*

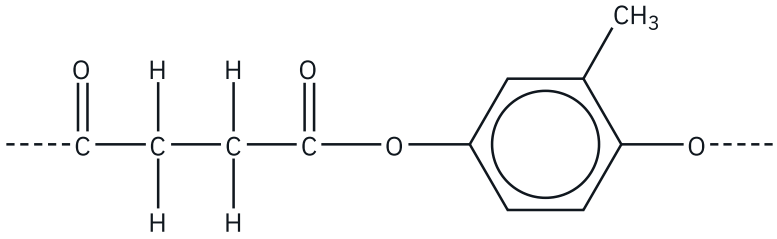
ALLOW *any consistent repeat unit:*

CH_2COOH and CH_3 groups can alternate or be on opposite sides of chain

e.g.



19(c)(ii)

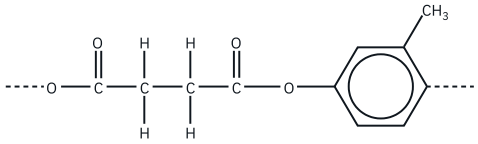


ester link ✓

ONE repeat units of correct polymer ✓

[2 marks]

end –O– may be at either side e.g.



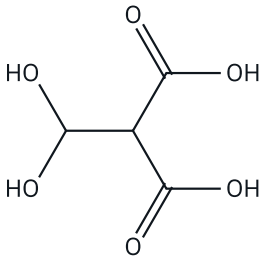
ALLOW *CH_3 to be on position 2 or 3 of the aromatic ring*

'End bonds' MUST be shown (do not have to be dotted)

IGNORE *brackets*

IGNORE *n*

19(c)(iii)

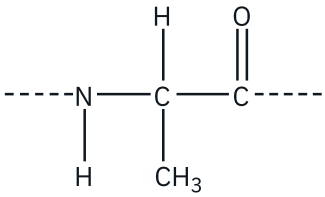


✓

[1 mark]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

19(d)(i)

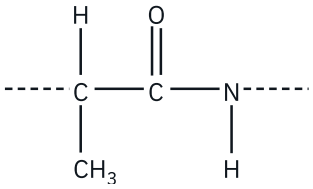


✓

ONE repeat unit ONLY

[1 mark]

end –N– may be at either side e.g.



'End bonds' MUST be shown (do not have to be dotted)

IGNORE *brackets*

IGNORE *n*

19(d)(ii)

IF *answer on answer line = 28418, AWARD 2 marks*

IF *answer on answer line = 28400, AWARD 1 mark*

ALLOW ECF *from incorrect repeat unit in 19di*

ALLOW ECF *from incorrect M_r of 400 repeat units*

M_r of 400 molecules = 400 × 89 = 35600 ✓

M_r of polymer = 35600 – (399 × 18) = 28418 ✓

[2 marks]

Alternative method based on repeat unit:

M_r of 400 repeat units = 400 × 71 = 28400 ✓

M_r of polymer = 28400 + 1 + 17 = 28418 ✓

19(e)

Level 3 (5–6 marks)

Correct calculation of mass of $CH_3CHClCOOH$.

AND

Planned synthesis includes substitution of –Cl and formation of compound I (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Calculation of mass of $CH_3CHClCOOH$ is correct

AND

Planned synthesis includes one step of the synthesis with the correct reagent and some conditions identified and equation is mostly correct

OR

Calculation of mass of $CH_3CHClCOOH$ is partly correct

AND

Planned synthesis includes substitution of –Cl and formation of compound I (or its corresponding ammonium salt) with the correct reagents

OR

Attempts to calculate mass of $CH_3CHClCOOC_2H_5$ but makes little progress

AND

Planned synthesis includes substitution of –Cl and formation of compound I (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Calculation of mass of $CH_3CHClCOOH$ is partly correct

OR

Planned synthesis includes both steps with some of the reagents and conditions identified

OR

Attempts equations for both steps but these may contain errors

Indicative scientific points may include:

Calculation of mass of $CH_3CHClCOOCH_3$

Using moles

- $n(I) = \frac{9.36}{117.0}$ = 0.08(00) (mol)
- $n(CH_3CHClCOOC_2H_5)$ $= \frac{0.0800 \times 100}{64}$ = 0.125 (mol)
- Mass of $CH_3CHClCOOH$ = 108.5 × 0.125 = 13.5625 g

Using mass

- Theoretical mass of I $= \frac{9.36 \times 100}{64}$ = 14.625 (g)
- Theoretical $n(CH_3CHClCOOH)$ $= \frac{14.625}{117.0}$ = 0.125 (mol)
- Mass of $CH_3CHClCOOH$ = 108.5 × 0.125 = 13.5625 g

***ALLOW** slip/rounding errors such as errors in M_r, e.g. use of 107.5 instead of 108.5 for $CH_3CHClCOOH$ → 13.4375*

Examples of partly correct calculations

Mass = 5.5552 g from $\frac{0.0800 \times 64}{100}$ × 108.5 (% yield inverted)

Mass = 8.68 g from 0.0800 × 108.5 (% yield omitted)

Synthesis: Either order for 2 stages

Substitution of –Cl → amine:

- Reagents: (excess) NH_3
- Condition: ethanol
- Equation: $CH_3CHClCOOH + 2NH_3 \rightarrow CH_3CHNH_2COOH + NH_4Cl$

OR

$CH_3CHClCOOH + NH_3 \rightarrow CH_3CHNH_2COOH + HCl$

OR

Describes one step of the synthesis with reagents, conditions and equation mostly correct

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

[6 marks]

Esterification of amine → compound I

- Reagents: CH_3CH_2OH
- Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat)
- Equation:

$CH_3CHNH_2COOH + CH_3CH_2OH \rightarrow CH_3CHNH_2COOCH_2CH_3 + H_2O$

OR

Esterification of carboxylic acid → ester

- Reagents: CH_3CH_2OH
- Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat)
- Equation:

$CH_3CHClCOOH + CH_3CH_2OH \rightarrow CH_3CHClCOOCH_2CH_3 + H_2O$

Substitution of –Cl → amine:

- Reagents: (excess) NH_3
- Condition: ethanol
- Equation: e.g

$CH_3CHClCOOCH_2CH_3 + 2NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + NH_4Cl$

OR

$CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + HCl$

OR

$CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_3ClCOOCH_2CH_3$ (ammonium salt)

Q53 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **D**

Q54 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **D**

Only 1

Q55 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **A**

$C_6H_5COCOOH$

Q56 · Carbonyls, carboxylic acids and esters · [14 marks]

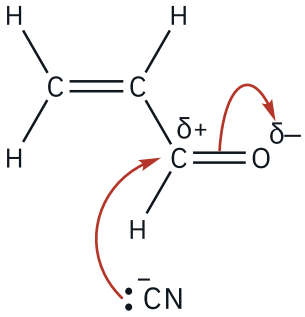
OCR MARK SCHEME

22(a)(i)

***NOTE**: curly arrows can be straight, snake-like, etc.*

but **NOT** double headed or half headed arrows

Nucleophilic attack 2 marks



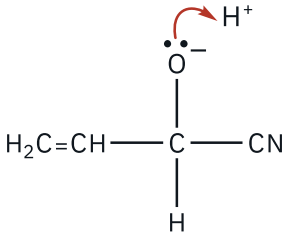
Curly arrow from $^{-}$CN to C of C=O ✓

Correct dipole shown on C=O

AND

curly arrow showing breaking of C=O ✓

Intermediate 1 mark



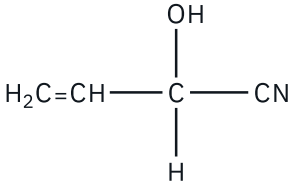
Correct intermediate

AND curly arrow from O^{-} to H^{+} ✓

***DO NOT ALLOW** δ– on O of intermediate*

***IGNORE** connectivity of H_2C=CH–*

Product 1 mark



Correct product ✓

Possible alternative 1,4 (conjugate) addition can be credited as follows (not in specification):

Nucleophilic attack 2 marks

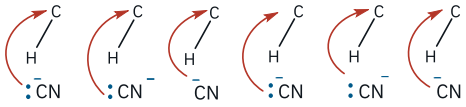
EXAMINER GUIDANCE

1st curly arrow must

- go to the C atom of C=O

AND

- start from, OR be traced back to any point across width of lone pair on C of $^{-}$:CN OR :CN^{-}
- OR start from – charge on C of $^{-}$CN (then lone pair on CN^{-} does not need to be shown)



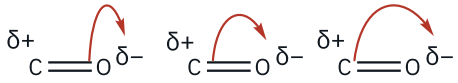
✓ ✓ ✓ ✓ ✗ ✗

2nd curly arrow must

- start from, OR be traced back to any part of $^{\delta+}$C=O$^{\delta-}$ bond

AND

- go to $O^{\delta-}$ (across width of $O^{\delta-}$)



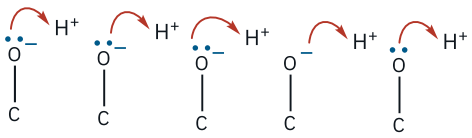
✓ ✓ ✗

3rd curly arrow must

- go to H^{+}

AND

- start from, OR be traced back to any point across width of lone pair on :O^{-}
- OR start from – charge of O^{-} of intermediate (then lone pair on O^{-} does not need to be shown)

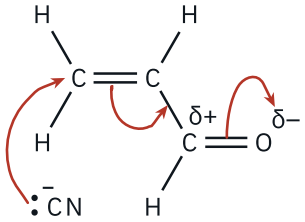


✓ ✓ ✗ ✓ ✗

***NOTE**: For arrow to H^{+}*

***ALLOW** arrow to H of H_2O*

i.e.



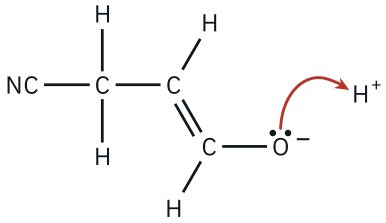
Curly arrow from $^{-}$CN to C of CH_2 of C=C ✓

Curly arrow from C=C to C-C

AND

curly arrow showing breaking of C=O ✓

Intermediate 1 mark



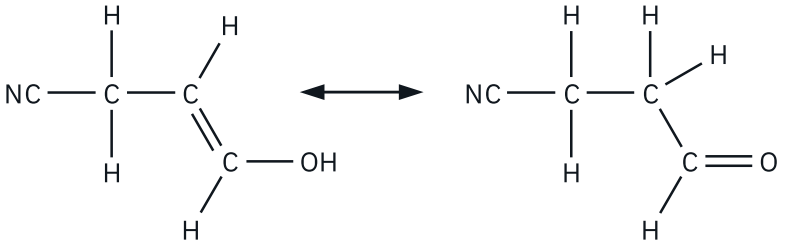
Correct intermediate

AND curly arrow from O^- to H^+ ✓

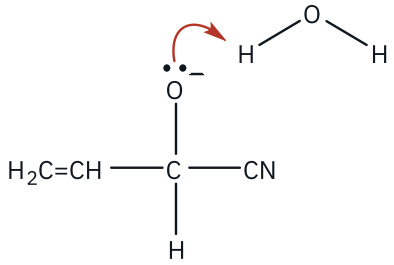
DO NOT ALLOW *δ– on O of intermediate*

Product 1 mark

Either tautomer as correct product ✓



[4 marks]



IGNORE *attempt to draw curly arrow showing breaking of H–O in H_2O*

IGNORE *lack of dipole on H_2O*

IGNORE *absence of OH^- as 2nd product*

Otherwise this more difficult mechanism could cost 2 marks

Product mark can only be given here if clear from mechanism that there is nucleophilic attack of CH_2 in C=C.

Same product could be seen with an attempt at electrophilic addition across C=C.

22(a)(ii)

Nucleophilic addition ✓

[1 mark]

IGNORE *just 'addition'*

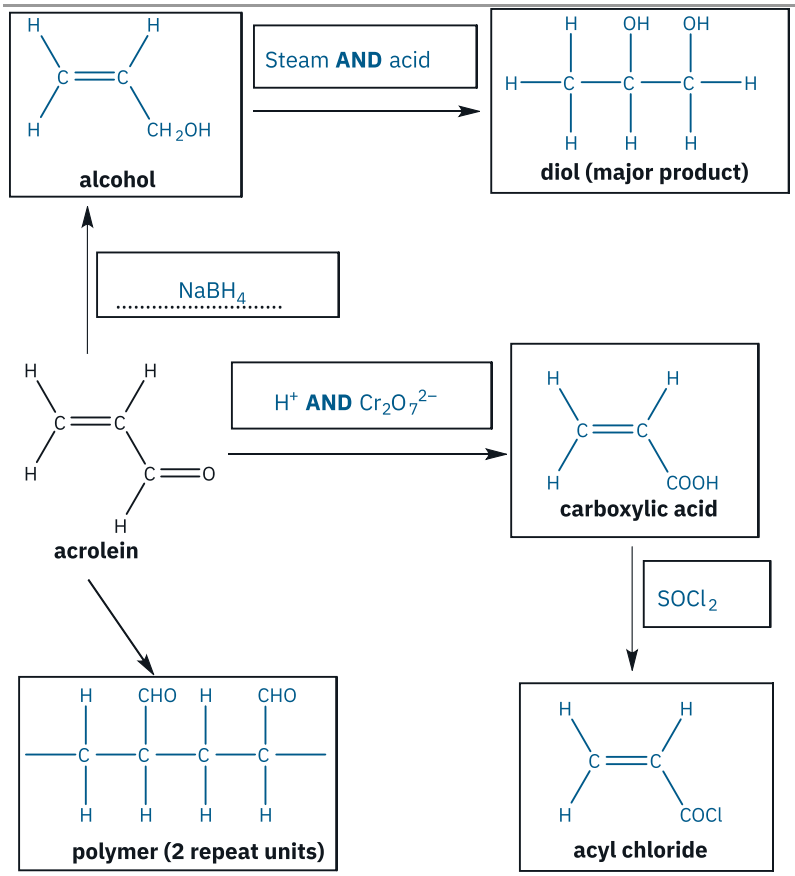
22(b)

ALLOW *any combination of skeletal OR structural OR displayed formula as long as unambiguous*

ALLOW *Correct names instead of formula for all reagents throughout e.g.*

For H^+ and $Cr_2O_7^{2-}$, **ALLOW** acidified dichromate

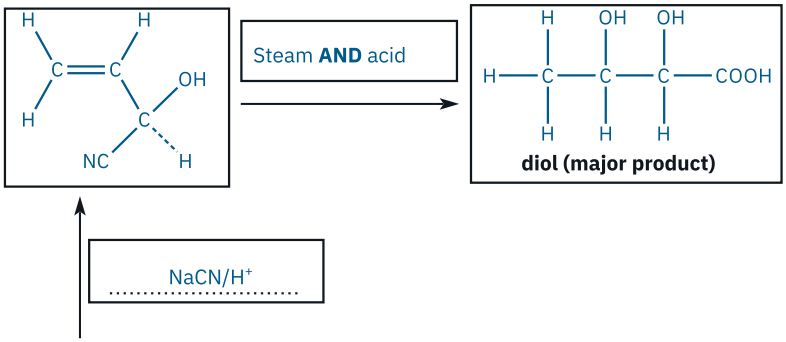
For Steam and acid



✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓

Only possible alternative that can gain credit:

Reaction with $NaCN/H^+$



✓ ✓ ✓ X

- For steam, **ALLOW** $H_2O(g)$ OR H_2O with T ≥ 100°C
- For acid, **ALLOW** H^+ OR H_2SO_4 OR H_3PO_4
- Note both needed for 1 mark. **ALLOW** either way round.

For $NaBH_4$

- **IGNORE** water / aqueous /acid
- **ALLOW** $LiAlH_4$

For $SOCl_2$, **ALLOW** PCl_5 OR $COCl_2$

- **IGNORE** H^+ OR HCl

For H^+ and $Cr_2O_7^{2-}$, **ALLOW** H_2SO_4 AND $K_2Cr_2O_7$ OR $Na_2Cr_2O_7$

ALLOW *Tollens' reagent*

IGNORE *connectivity except*

DO NOT ALLOW *-COH for aldehyde*

For polymer **ALLOW** alternating side chains.

IGNORE *brackets and use of 'n'*

'End bonds' MUST be shown (solid or dotted)

IF *$NaCN/H^+$ reacted with acrolein instead of $NaBH_4$*

- No mark for $NaCN/H^+$ OR HCN
- Unsaturated alcohol award mark for product as shown
- Final product must have CN hydrolysed as shown

[9 marks]

Q57 · Carbonyls, carboxylic acids and esters · [8 marks]

OCR MARK SCHEME

17(a)

Reagent and/or catalyst:

H_2SO_4 OR H_3PO_4 OR H^+ OR acid (catalyst) ✓

Organic product: (mark independently)

$CH_3CH_2CHCH_2$ ✓

[2 marks]

EXAMINER GUIDANCE

DO NOT ALLOW *other named acids e.g. HCl / hydrochloric acid as can be used for substitution reaction*

DO NOT ALLOW *other additional reagents e.g. H_2O / steam, H_2 / hydrogen*

ALLOW suitable non-specification alternatives e.g. Al_2O_3 OR Pumice stone

ALLOW names of reagents e.g. sulfuric or phosphoric acid, if no formulae given

IGNORE *concentration e.g. dilute/concentrated*

IGNORE *(aq) state symbol*

IGNORE *conditions e.g. temperature/pressure/reflux*

ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

IGNORE *names unless no structure is given then accept but-1-ene*

17(b)

Reagent and/or catalyst:

$K_2Cr_2O_7$ **AND** H_2SO_4

OR $Cr_2O_7^{2-}/H^+$ ✓

Organic product: (mark independently)

$CH_3CH_2COCH_3$ ✓

[2 marks]

ALLOW $Na_2Cr_2O_7$ *for* $K_2Cr_2O_7$

ALLOW names for reagents e.g. acidified dichromate, if no formulae given

IGNORE *Roman numerals e.g. (VI), unless incorrect*

IGNORE *[O]*

DO NOT ALLOW *other named acids e.g. HCl / hydrochloric acid*

DO NOT ALLOW *other additional reagents e.g.* H_2O*, steam*

ALLOW suitable non-specification alternative oxidising agents e.g. $KMnO_4/H^+$ *OR* CrO_3/H^+ *OR* H_2CrO_4 *(chromic acid)*

IGNORE *concentration e.g. dilute/concentrated*

IGNORE *conditions e.g. reflux/distillation*

ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

IGNORE *names unless no structure is given then accept butanone*

17(c)

Mark organic product first:

$(CH_3)_2CHCH_2X$

where X is identified as Cl, Br, I ✓

Reagent and/or catalyst:

Reagent to match organic product

NaX / KX / X^-

AND

H_2SO_4 / H^+ / acid

Where X is identified as Cl, Br, I ✓

ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

IGNORE *names unless no structure is given then accept 1-halo-2-methylpropane, where halo is chloro, bromo or iodo (ignore alphabetical order for prefixes)*

For 2 marks, the reagent must be consistent with the product given e.g. $(CH_3)_2CHCH_2Cl$ then correct reagent is NaCl / H_2SO_4

[2 marks]

ALLOW 1 mark if correct reagents given but no or incorrect organic product shown

*ALLOW 1 mark if organic product is given with X i.e. $(CH_3)_2CHCH_2X$ **AND** reagent is consistent e.g. NaX / H^+ OR just states 'halide with acid'*

ALLOW HX where X is identified as Cl, Br, I

ALLOW names of reagents e.g. sodium bromide and sulfuric acid, if no formulae given

***DO NOT ALLOW** other additional reagents e.g. $AlCl_3$*

*ALLOW suitable non-specification alternative e.g. PCl_3, PCl_5, (red) phosphorus **AND** bromine OR iodine, $SOCl_2$*

***IGNORE** concentration e.g. dilute/concentrated*

***IGNORE** conditions e.g. reflux/distillation*

17(d)

Mark organic product first:

A correct ester of $(CH_3)_3COH$ ✓

e.g. $(CH_3)_3COOCCH_3$

Reagent and/or catalyst:

Reagent to match ester shown

suitable carboxylic acid **AND** acid / H^+ catalyst, e.g. CH_3COOH/H_2SO_4

OR

suitable acyl chloride e.g. CH_3COCl

OR

suitable acid anhydride e.g. $(CH_3CO)_2O$ ✓

[2 marks]

ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

***IGNORE** additional byproducts e.g. H_2O, HCl or carboxylic acid (from acid anhydride)*

For 2 marks, the reagent must be consistent with the product given e.g. $(CH_3)_3COOCCH_3$ then correct reagent is CH_3COOH / H_2SO_4

ALLOW 1 mark if correct reagents given but no or incorrect organic product shown

*ALLOW 1 mark if ester is given with an R group i.e. $(CH_3)_3COOCR$ **AND** reagent is consistent e.g. RCOOH OR just states 'carboxylic acid and acid'*

ALLOW names of reagents e.g. ethanoic acid and sulfuric acid.

***DO NOT ALLOW** other additional reagents e.g. $Cr_2O_7^{2-}$*

***IGNORE** concentration e.g. dilute/concentrated*

***IGNORE** conditions e.g. reflux/distillation*

***IGNORE** use of acid catalyst with acyl chloride or acid anhydride*

Q58 · Carbonyls, carboxylic acids and esters · [13 marks]

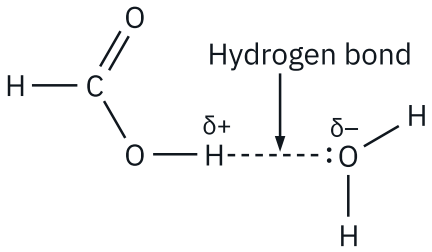
OCR MARK SCHEME EXAMINER GUIDANCE

20(a)

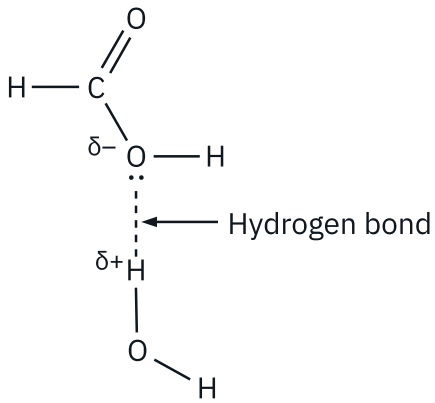
Diagram showing a hydrogen bond between a water molecule and a HCOOH (dipoles and lone pairs not required)

AND

Hydrogen bonding / H-bond stated **OR** labelled on diagram ✓



OR



H bond originates from lone pair on δ- O and goes to δ+ H (on another molecule) ✓

[2 marks]

*ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

ALLOW hydrogen bond to $HCOO^-$ (methanoate ion)

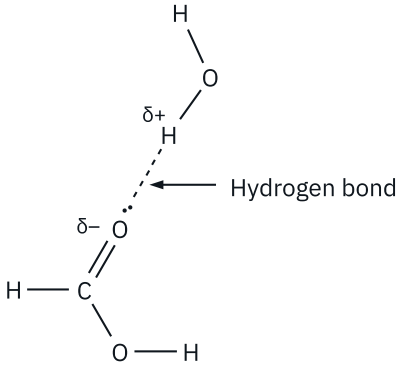
***DO NOT ALLOW** H bond from H–C*

***DO NOT ALLOW** any marks for a diagram containing O_2H*

Hydrogen bond does **NOT** need to be labelled but it must be different from the covalent bond if it is not labelled.

***IF** more than one hydrogen bond is shown they must ALL be correct to award each mark.*

ALLOW H bond between C=O and H_2O, i.e.



***DO NOT ALLOW** δ+ on H atom of C-H*

All Hydrogen bonds must hit a lone pair

ALLOW only one lone pair on O atom

***DO NOT ALLOW** more than 2 lone pairs on O atom*

20(b)(i)

ethyl 4-methylpentanoate ✓

[1 mark]

ALLOW one word: ethyl4-methylpentanoate

OR more words, e.g. ethyl 4-methyl pentanoate

***DO NOT ALLOW** 1-ethyl-4-methylpentanoate*

***IGNORE** lack of hyphens, extra hyphens, full stops instead of commas, extra spaces*

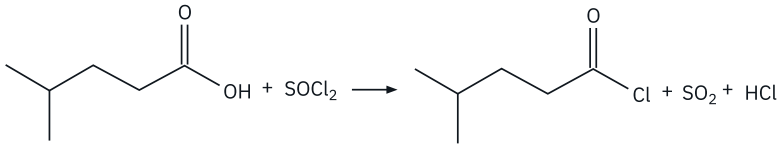
***DO NOT ALLOW** the following for methyl: methy, meth, methly, methanyl*

***DO NOT ALLOW** the following for ethyl: ethy, eth, ethly, ethanyl*

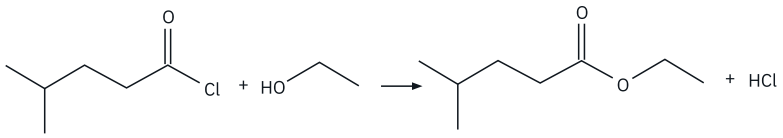
20(b)(ii)

Step 1

*ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as*



Step 2



$SOCl_2$ used in Step 1 ✓

Acyl chloride: $(CH_3)_2CHCH_2CH_2COCl$ correct ✓

Seen anywhere

Step 1 correct equation ✓

Step 2 correct equation ✓

[4 marks]

unambiguous

e.g. $(CH_3)_2CHCH_2CH_2COOH + SOCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + SO_2 + HCl$

$(CH_3)_2CHCH_2CH_2COCl + C_2H_5OH \rightarrow (CH_3)_2CHCH_2CH_2COOC_2H_5 + HCl$

DO NOT ALLOW *incorrect connectivity on OH*

BUT **ALLOW ECF** on subsequent structures

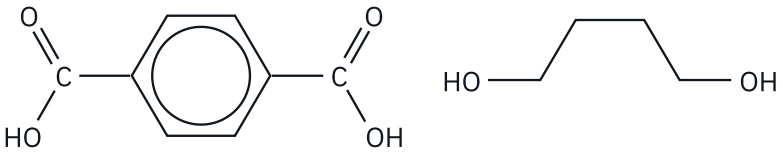
ALLOW suitable non-specification alternatives for step 1 e.g. PCl_3, PCl_5, $COCl_2$

e.g. $3(CH_3)_2CHCH_2CH_2COOH + PCl_3 \rightarrow 3(CH_3)_2CHCH_2CH_2COCl + H_3PO_3$

$(CH_3)_2CHCH_2CH_2COOH + PCl_5 \rightarrow (CH_3)_2CHCH_2CH_2COCl + POCl_3 + HCl$

$(CH_3)_2CHCH_2CH_2COOH + COCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + HCl + CO_2$

20(c)

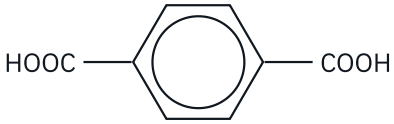


✓ ✓

[2 marks]

*ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

e.g. ALLOW



✓

$HO–CH_2CH_2CH_2CH_2–OH$ ✓

ALLOW Diacyl chloride:



✓

ALLOW a diacid anhydride of benzene-1,4-dicarboxylic acid, e.g.



✓

DO NOT ALLOW *incorrect connectivity on OH*

BUT **ALLOW ECF** on subsequent structures

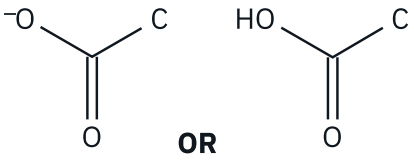
ALLOW correct Kekulé representation of benzene

20(d)

Hydrolysis of ester:

Methanol / CH_3–OH ✓

Formation of carboxylate / carboxylic acid from hydrolysis of ester or amide:

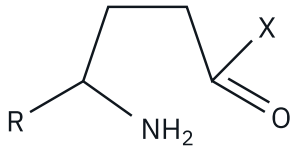


✓

C=O of Carboxylate or carboxylic acid group must be attached to a C
But ignore rest of molecule

Hydrolysis of amide:

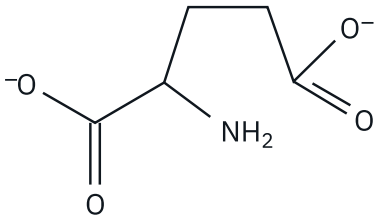
Breaks amide bond in ring to give: ✓



Where R can be H or any other structure

For X, ignore group attached to C=O

Correct hydrolysis product:



✓

*ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

***DO NOT ALLOW** incorrect connectivity on OH*

...BUT **ALLOW ECF** on subsequent structures

***DO NOT ALLOW** CH_3O^- (Na^+) **OR** sodium methoxide*

*ALLOW $–COO^-Na^+$ **OR** –COONa*

***DO NOT ALLOW** esters or amides*

ALLOW NH_3^+

***IGNORE** missing Hs on carbon chain*

Must be completely correct structure

*ALLOW $–COO^-Na^+$ **OR** –COONa*

[4 marks]

Q59 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **B**

Only 1 and 2

Q60 · Carbonyls, carboxylic acids and esters · [17 marks]

OCR MARK SCHEME

21(a)

An atom/ group of atoms/part of molecule responsible for the characteristic reactions (of a compound) ✓

[1 mark]

EXAMINER GUIDANCE

***ALLOW** 'part of an organic compound' for 'part of molecule'*

***ALLOW** 'chemical properties' **OR** 'reactions **OR** 'reactivity' for 'characteristic reactions'*

21(b)

2,4-DNP ✓

Red/orange/yellow precipitate ✓

[2 marks]

IGNORE *references to physical properties*

ALLOW *2,4-dinitrophenylhydrazine* ***OR*** *2,4-DNPH*

OR Brady's (Reagent)

ALLOW *ppt* ***OR*** *solid* ***OR*** *crystals as an alternative for precipitate*

Mark second point independently of response for first marking point

21(c)

	Expected observations		
Chemical test	**Pyruvic acid**	**Methylglyoxal**	**Acetol**
Tollens' reagent	no change	Silver mirror	no change **OR** Silver mirror
Na_2CO_3(aq)	Effervescence **OR** Bubbles **OR** Fizzing	no change	no change
$Cr_2O_7^{2-}$(aq) / H^+(aq)	no change (orange solution)	(Orange to) Green (solution)	(Orange to) Green (solution)

One row correct ✓

Two rows correct ✓✓

Three rows correct ✓✓✓

[3 marks]

ALLOW *alternatives for 'no change' such as 'no observation', 'no reaction', 'nothing' or 'X'*

For Tollen's

ALLOW *Silver/Grey/Black* ***AND*** *precipitate/ppt/solid*

ALLOW *acetol to give a positive result (it is an alpha hydroxy ketone so can tautomerize to give an aldehyde, not covered in the specification)*

For Na_2CO_3

IGNORE *gas / CO_2 formed i.e. must be an observable change*

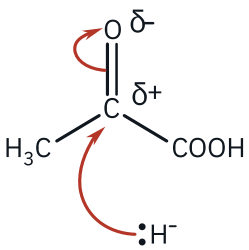
IGNORE *test with limewater* ***BUT DO NOT ALLOW*** *other gas tests*

If no other marks awarded, ***ALLOW*** *1 mark for a correct column*

21(d)

NOTE*: curly arrows can be straight, snake-like, etc. but* ***NOT*** *double headed or half headed arrows*

Nucleophilic attack 2 marks



Curly arrow from H^- to C of C=O ✓

Correct dipole shown on C=O

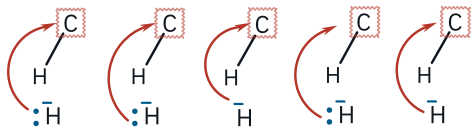
AND

1st curly arrow must

- go to the C atom of C=O

AND

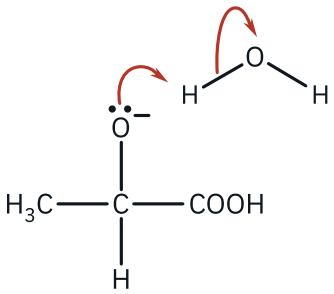
- start from, **OR** be traced back to any point across width of lone pair on $^-$:H
- **OR** start from – charge on $^-$H (then lone pair on H^- does not need to be shown)



✓ ✓ ✓ ✓ ✗

curly arrow showing breaking of C=O ✓

Intermediate 1 mark



Correct intermediate

AND curly arrow from O^- to H in H_2O ✓

DO NOT ALLOW *δ– on O of intermediate*

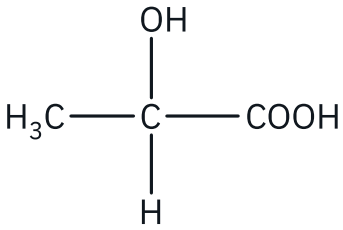
IGNORE *attempt to draw curly arrow showing breaking of H–O in H_2O*

IGNORE *lack of dipole on H_2O*

IGNORE *absence of OH^- as 2nd product*

IGNORE *connectivity of H_3C–*

Product 1 mark



Correct product ✓

[4 marks]

21(e)

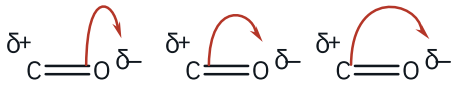
IF *the carboxylic acid is attacked, in addition to the ketone, then* ***ALLOW*** *first two marks provided all arrows and dipoles are correct*

2nd curly arrow must

- start from, **OR** be traced back to any part of $^{\delta+}C=O^{\delta-}$ bond

AND

- go to $O^{\delta-}$ (across width of $O^{\delta-}$)



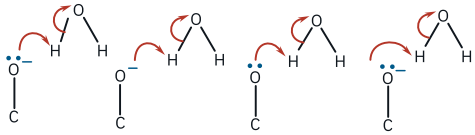
✓ ✓ ✗

3rd curly arrow must

- go to H of H_2O

AND

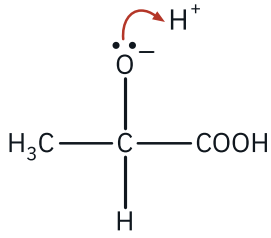
- start from, **OR** be traced back to any point across width of lone pair on $:O^-$
- **OR** start from – charge of O^- of intermediate



✓ ✓ ✗ ✗

NOTE: For arrow to *H of H_2O*

ALLOW *curly arrow from O^- of intermediate to H^+*



IGNORE *Connectivity*

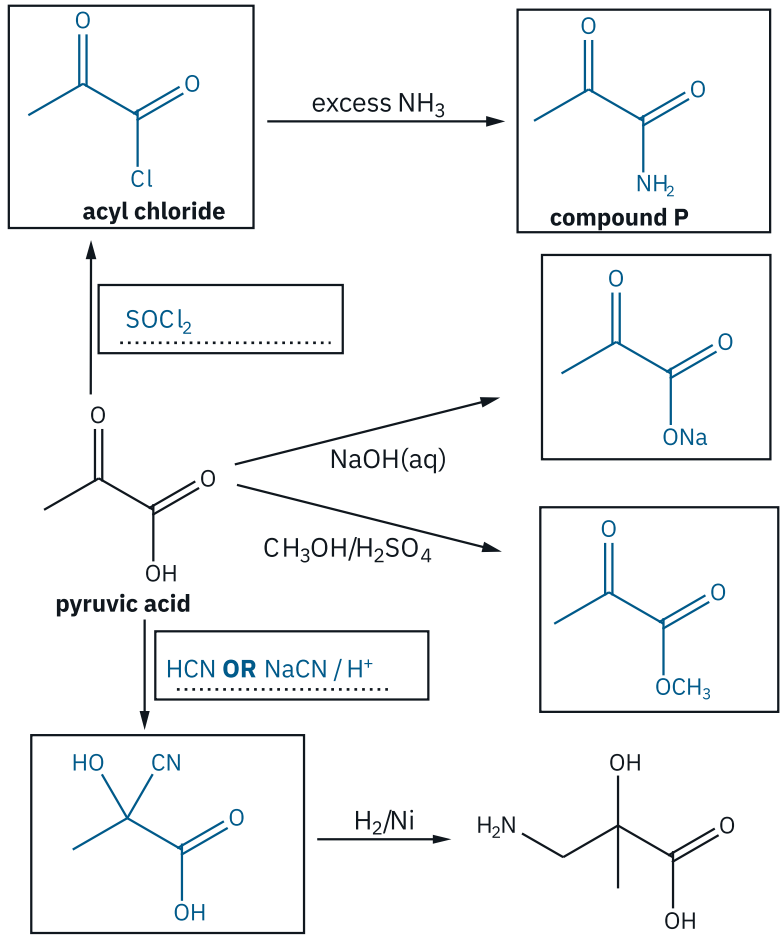
ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *names for reagents if no formulae given*

IGNORE *connectivity*

IGNORE *conditions*

IGNORE *inorganic products*



✓✓✓✓✓✓✓

[7 marks]

DO NOT ALLOW *$-CONH_3^+$ in compound P*

For $SOCl_2$, **ALLOW** PCl_3 **OR** PCl_5 **OR** $COCl_2$

IGNORE *additional H^+* ***OR*** *HCl* ***OR*** *H_2SO_4*

DO NOT ALLOW *H_2O or (aq)*

ALLOW *carboxylate ion, COO^- (Na^+)*

ALLOW

NaCN **OR** KCN **OR** CN^-

AND

H^+ **OR** H_2SO_4 **OR** HNO_3 **OR** HCl

Acid is required for mark

IGNORE *solvent* ***OR*** *(aq)*

ALLOW *any vertical bond to the OH or CN*

e.g. **ALLOW**



BUT DO NOT ALLOW -HO **OR** -NC

Q61 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **D**

ALLOW *A*

Q62 · Carbonyls, carboxylic acids and esters · [11 marks]

OCR MARK SCHEME

18(a)(i)

Reagents

$K_2Cr_2O_7$ **AND** acid

AND reflux ✓

Equation

$HO(CH_2)_4OH + 4[O] \rightarrow HOOC(CH_2)_2COOH + 2H_2O$

[O] **AND** H_2O ✓

Correctly balanced equation ✓

[3 marks]

EXAMINER GUIDANCE

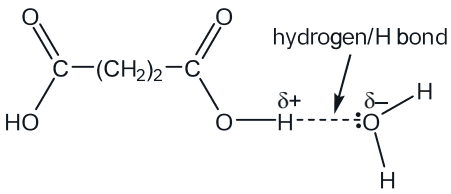
ALLOW *$Na_2Cr_2O_7$* ***OR*** *$Cr_2O_7^{2-}$*

ALLOW *H_2SO_4* ***OR*** *HCl* ***OR*** *H^+*

ALLOW *words. e.g. 'acidified dichromate'*

ALLOW *a small slip in formula for dichromate e.g KCr_2O_7,*

18(a)(ii)



OR

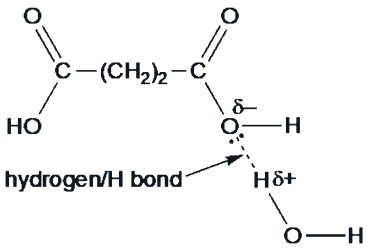


Diagram showing correct dipole charges on each end of one hydrogen bond between a water molecule and a diacid ✓

Hydrogen bond between one lone pair on O atom in one of the molecules and the H atom of another

AND

Hydrogen bonding stated or labelled on diagram

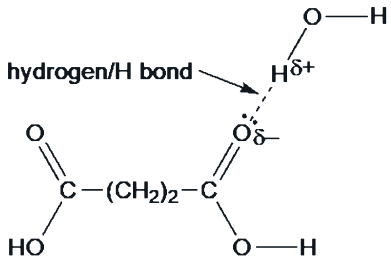
[2 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

DO NOT ALLOW *δ+ on H atoms of CH_2 group*

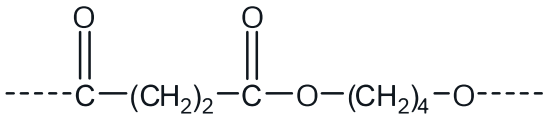
ALLOW *H-bond for hydrogen bond*

ALLOW *H bond between C=O and H_2O, i.e.*



IF *diagram is not labelled,* ***ALLOW*** *hydrogen bond/H bond from text*

18(b)(i)

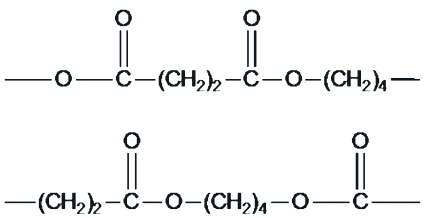


Ester link (must be displayed) ✓

Rest of structure ✓

[2 marks]

ALLOW *the 'O' or C=O at either end, e.g.*



IGNORE *brackets*

IGNORE *n*

End bonds' MUST be shown (solid or dotted)

DO NOT ALLOW *more than one repeat unit*

IGNORE *references to photodegradable*

'Bond breaks' is not sufficient – no reference to ester bond

18(b)(ii)

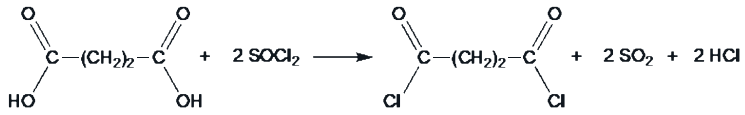
the ester/ ester bond/ ester group /polyester can be broken down ✓

OR

It can be hydrolysed ✓

[1 mark]

18(b)(iii)



$SOCl_2$ in equation ✓

Structure of diacyl dichloride ✓

Complete balanced equation ✓

[3 marks]

ALLOW *alternative approach using* PCl_5 *or* PCl_3

Q63 · Carbonyls, carboxylic acids and esters · [14 marks]

OCR MARK SCHEME

EXAMINER GUIDANCE

19(a)(i)

(series of organic compounds with the) same functional group **OR** same/similar chemical properties/reactions ✓

each successive/subsequent member differs by CH_2 ✓

[2 marks]

IGNORE *reference to physical properties*

IGNORE *same general formula*

DO NOT ALLOW *same empirical* ***OR*** *molecular formula*

Differs by CH_2 is not sufficient (no successive)

19(a)(ii)

$C_{24}H_{48}O$ ✓

[1 mark]

19(b)

F/aldehyde

AND

Tollens' (reagent)

AND

Silver (mirror/precipitate/ppt/solid) ✓

G/alkene/C=C

AND

Bromine/Br_2

AND

goes colourless/decolourised ✓

G/ketone

IGNORE *use of 2,4-DNP with F*

ALLOW *ammoniacal silver nitrate* ***OR*** Ag^+/NH_3

ALLOW *black ppt* ***OR*** *grey ppt*

ALLOW *bromine water/* $Br_2(aq)$

ALLOW *errors in spelling for 2,4-DNP*

ALLOW *2,4(-)DNP* ***OR*** *2,4(-)DNPH*

ALLOW *Brady's reagent or Brady's Test*

ALLOW *solid* ***OR*** *crystals* ***OR*** *ppt as alternatives for precipitate*

ALLOW *ammoniacal silver nitrate* ***OR*** Ag^+/NH_3

AND

2,4-dinitrophenylhydrazine

AND

orange/yellow/red precipitate ✓

G/ketone

AND

Tollens' (reagent)

AND

no silver mirror/no change/no reaction ✓

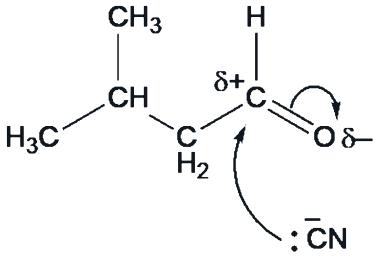
ALLOW *black ppt* ***OR*** *grey ppt*

ALLOW *alterative approach using acidified potassium dichromate for tests with F and/or G, with correct observations, alongside use of 2,4-DNP*

[4 marks]

19(c)(i)

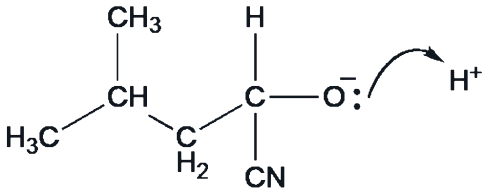
Mechanism 3 marks



Curly arrow from $^{-}$CN to C atom of C=O ✓

Dipole shown on C=O bond, $C^{\delta+}$ and $O^{\delta-}$,

AND curly arrow from C=O bond to O atom ✓

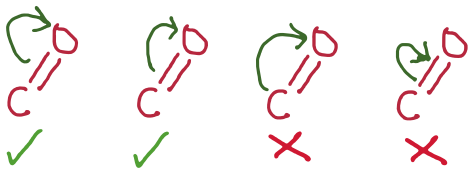


Curly arrow from lone pair **OR** – charge on O^{-} of correct intermediate to H^{+} ✓

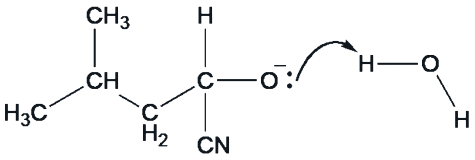
Curly arrow must come from lone pair on C of $^{-}$CN **OR** CN^{-}

OR from minus sign on C of $^{-}$CN ion (then lone pair on CN^{-} does not need to be shown)

Curly arrow from C=O bond must start from, OR be traced back to, any part of C=O bond and go to O



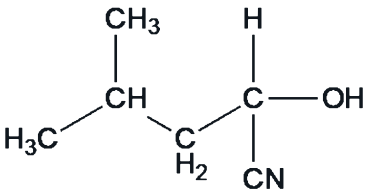
ALLOW *curly arrow to H atom of H_2O, i.e.*



IGNORE *attempt to draw curly arrow showing breaking of H–O in H_2O*

IGNORE *lack of dipole on H_2O*

Product 1 mark



✓

Name of mechanism 1 mark

Nucleophilic addition ✓

[5 marks]

19(c)(ii)

ALLOW *2 electrons go to one (bonded)*

Heterolytic

One (bonded) atom/O receives both/2 electrons ✓

Fission

Breaking of a covalent bond ✓

[2 marks]

atom/O

DO NOT ALLOW *both pairs of electrons go to O*

IGNORE *formation of ions/radicals*

For O atom,

ALLOW *species*

DO NOT ALLOW *element or molecule*

ALLOW *π bond in C=O breaks*

IGNORE *breaking of C=O bond (no reference to only one bond breaking)*

'Bond breaking' is not sufficient

(no reference to covalent)

Q64 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **A**

NaCN in ethanol

Q65 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **D**

$(CH_3)_2CHCH_2COOCH_2CH_3$

Q66 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **D**

The organic product has the molecular formula $C_7H_{11}NO$.

Q67 · Carbonyls, carboxylic acids and esters · [1 mark]

Answer: **B**

CH_3CH_2COONa and CH_3OH

Q68 · Chromatography and functional group tests · [12 marks]

OCR MARK SCHEME

5(a)(i)

For 5a(i)–(iv) IGNORE poor connectivity to SH groups

Given in question

$$K_a = \frac{[H^+]\,[C_4H_9S^-]}{[C_4H_9SH]}$$ ✓

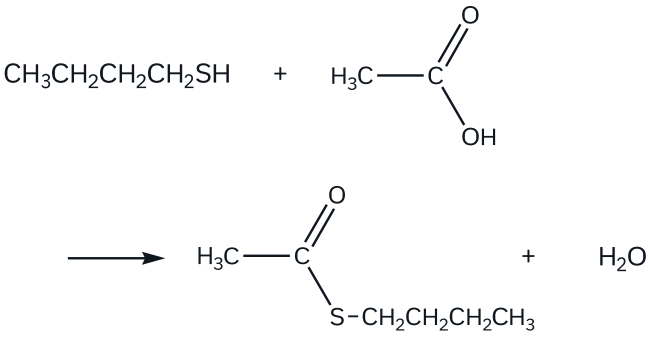
Square brackets required

[1 mark]

EXAMINER GUIDANCE

ALLOW *correct structural* ***OR*** *skeletal* ***OR*** *displayed formula* ***OR*** *mixture of the above as long as non-ambiguous*

5(a)(ii)



Structure of thioester ✓

Complete equation ✓

[2 marks]

ALLOW *correct skeletal* ***OR*** *displayed formula* ***OR*** *mixture of the above as long as non-ambiguous*

ALLOW C_4H_9SH

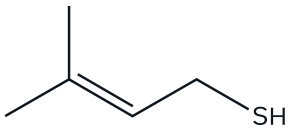
ALLOW CH_3COOH

Thioester functional group must be fully displayed,

OR as a skeletal formula

but allow SC_4H_9 in thioester

5(a)(iii)

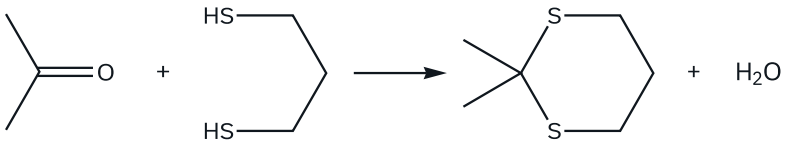


✓

[1 mark]

IF *correct skeletal formula is shown, IGNORE displayed formula in a second structure*

5(a)(iv)



Reactants ✓

Products **AND** balanced equation ✓

[2 marks]

ALLOW *correct structural* ***OR*** *skeletal* ***OR*** *displayed formula* ***OR*** *mixture of the above as long as non-ambiguous*

5(b)

Level 3 (5–6 marks)

Develops a plan that identifies all compounds by a process of elimination

Indicative scientific points may include:

Functional groups

- B alkene and tertiary alcohol
- C alkene and aldehyde

AND

includes essential detail for all required tests and observations

There is a well-developed line of reasoning which is clear and logically structured

Level 2 (3–4 marks)

Develops a plan that identifies at least half of the compounds **OR** identifies the functional groups in most of the compounds

AND

includes detail of the required tests and observations

There is a line of reasoning with some structure. The information is mostly relevant and supported by some evidence.

Level 1 (1–2 marks)

Develops a plan that attempts to identify the compounds **OR** functional groups

AND

includes detail of the required tests and observations

There is a line of reasoning using information that is mostly relevant.

0 marks – No response or no response worthy of credit with no compounds identified

Appendix for Q5b Level of Response

Results of tests

	B	C	D	E	F	G
Bromine	✓	✓	✓			✓
$(H^+/)Cr_2O_7^{2-}$		✓	✓		✓	
2,4-DNP		✓		✓		✓
Tollens		✓				

Possible processes of elimination (not inclusive)

- D alkene and primary alcohol
- E ketone
- F secondary alcohol
- G alkene and ketone

Tests

- B, C, D and G → Bromine decolourises
- C, D and F → $(H^+/)Cr_2O_7^{2-}$ green
- C, E and G → 2,4-DNP orange precipitate
- C → Tollens silver mirror

For Tollens' **ALLOW** alternative: Fehling's solution produces a 'brown/brick red/orange precipitate

For 2,4-DNP, **ALLOW** 2,4-DNPH and Brady's

	B	C	D	E	F
Bromine	✓	✓	✓		
$(H^+/)Cr_2O_7^{2-}$		✓	✓		✓
2,4-DNP		✓		✓	
Tollens'		✓			

No credit for tests on products of tests, melting points, spectra, etc.

BCDEFG with 2,4 DNP	**CEG** orange ppt		
	CEG with Tollens	**C** silver mirror	
	EG with bromine	**G** decolourises	**E** no change
BDF with **$(H^+)/Cr_2O_7^{2-}$**	**DF** green	**B** no colour change	
	DF with bromine	**D** decolourises	**F** no change

BCDEFG with **$(H^+)/Cr_2O_7^{2-}$**	**CDF** green		
	CDF with Tollens/2,4DNP	**C** silver mirror/orange ppt	
	DF with bromine	**D** decolourises	**F** no change
BEG with 2,4 DNP	**EG** orange ppt	**B** no change	
	EG with bromine	**G** decolourises	**E** no change

BCDEFG with **bromine**	**BCDG** decolourise	**EF** no change	
	EF with 2,4-DNP/**$(H^+/)Cr_2O_7^{2-}$**	**E** orange ppt/**F** green	
	BCDG with Tollens'	**C** silver mirror	**BDG** no change
	BDG with **$H^+/Cr_2O_7^{2-}$**	**D** green	**BG** no change
	BG with 2,4-DNP	**G** orange ppt	**B** no change

[6 marks]

Q69 · Chromatography and functional group tests · [1 mark]

Answer: **C**

Only 2 and 3

Q70 · Chromatography and functional group tests · [13 marks]

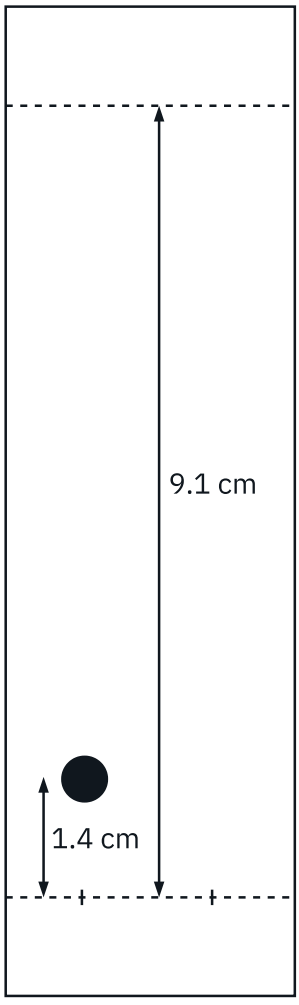
OCR MARK SCHEME

5(a)(i)

$R_f \sim \frac{1.4}{9.1}$ in cm OR $\frac{14}{91}$ in mm = 0.15 ✓

Working required

Check for ~ 9.1 as denominator



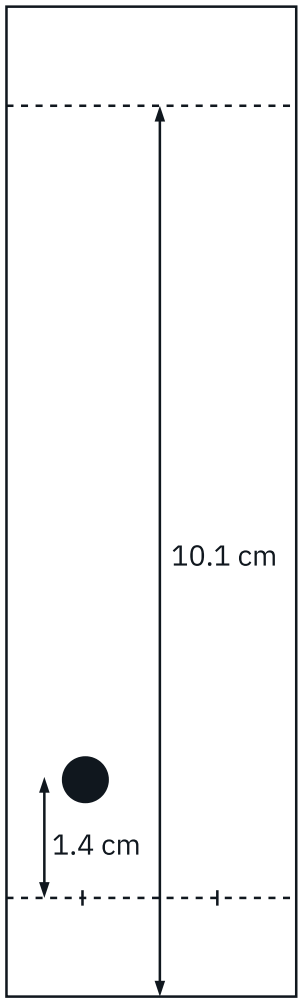
[1 mark]

EXAMINER GUIDANCE

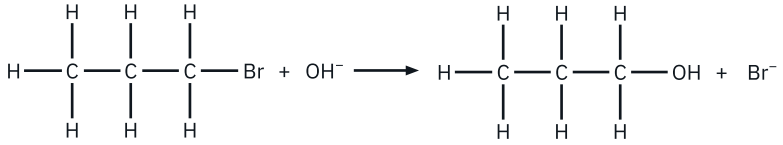
ALLOW *0.12 – 0.18 (i.e. ±0.03)*

DO NOT ALLOW $\frac{1.4}{10.1}$ *= 0.14*

10.1 measured from bottom of plate to solvent front



5(a)(ii)



✓

ALLOW *any combination of skeletal OR structural OR displayed formula as long as unambiguous*

DO NOT ALLOW *Missing H atoms*

DO NOT ALLOW *H_2O and HBr*

Question asks for alkaline hydrolysis

Correct balanced equation

ALLOW *OH^- above the arrow*

DO NOT ALLOW *if a CON reagent is present,*

e.g. an acid

For OH^- and Br^-

ALLOW *KOH and KBr OR NaOH and NaBr*

BUT **DO NOT ALLOW** K–OH

implies covalent bond

[1 mark]

DO NOT ALLOW *C_3H_7, i.e. C_3H_7Br OR C_3H_7OH*

Structure asked for in Question

IGNORE *connectivity, e.g.*

ALLOW



BUT **DO NOT ALLOW** —HO

5(a)(iii)

Difference

propan-1-ol/product/bottom spot is smaller

OR 1-chloropropane/reactant/top spot bigger ✓

Reasons

C–Cl bond is stronger than C–Br

AND

1-chloropropane reacts slower/is less reactive ✓

Use of propan-1-ol

shows formation of propan-1-ol

OR shows when reaction has finished

OR monitors course/progress of reaction ✓

[3 marks]

ALLOW ECF *and* ***ORA*** *throughout*

IGNORE *references to halogens as elements:*

i.e. chlorine is less reactive than bromine etc.

DO NOT ALLOW *chloride, bromide*

DO NOT ALLOW *1-chloropropane has larger bond enthalpy*

C–Cl bond required

IGNORE *1-chloroproane has different R_f value*

IGNORE *'as a control' OR 'as a comparison'*

..... with no further explanation

5(b)(i)

Green solution Cr^{3+} OR $[Cr(H_2O)_6]^{3+}$ ✓

Orange solution $Cr_2O_7^{2-}$ ✓

Formulae **AND** charges must be correct

[2 marks]

Green solution

IGNORE *H^+*

ALLOW *$Cr_2(SO_4)_3$ OR $CrCl_3$ OR Cr^{+3}*

Orange solution

IGNORE *H^+*

ALLOW *$K_2Cr_2O_7$ OR $Na_2Cr_2O_7$*

DO NOT ALLOW *Cr^{6+}*

ALLOW *1 mark for correct formulae but wrong way round*

5(b)(ii)

Level 3 (5–6 marks)

Reaches a comprehensive conclusion to determine possible correct structures for ALL of F, G, H and I

AND ALL functional groups of F, G, H and I

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Indicative scientific points may include:

Identity of F, G, H and I showing CORRECT structures

Level 2 (3–4 marks)

Reaches a conclusion to determine possible correct structures for two of F, G, H and I

AND most functional groups of F, G, H and I

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Reaches a simple conclusion to determine a possible correct structure for one of F, G, H and I

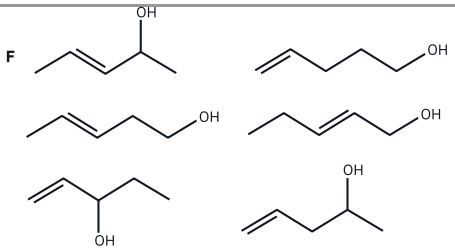
OR some functional groups of F, G, H and I

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

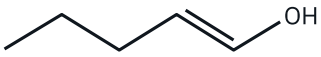
0 marks No response or no response worthy of credit.

[6 marks]

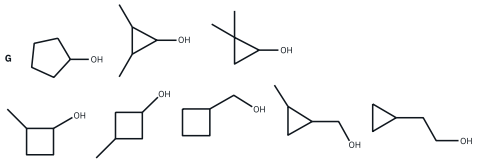
F



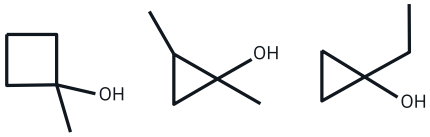
ALLOW *enols for F, e.g.*



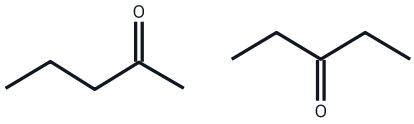
G



For G, **DO NOT ALLOW** tertiary –OH. e.g.



H



I



IGNORE *names, even if incorrect*

For communication, a typical 'logical structure' would link functional groups to SOME of the test results,

e.g.

2,4-DNP

H and I have carbonyl group/aldehyde or ketone

$H^+/Cr_2O_7^{2-}$

F, G and I are primary or secondary alcohols or aldehydes

Bromine

F is unsaturated/has C=C

Tollens

I is aldehyde

Correct functional groups may be shown in correct structures

Q71 · Chromatography and functional group tests · [1 mark]

Answer: **B**

Only 1 and 2

Q72 · Chromatography and functional group tests · [6 marks]

OCR MARK SCHEME

22(a)(i)

Calculation of R_f values

$R_f = \frac{34.5}{46} = 0.75$

AND

$R_f = \frac{11.5}{46} = 0.25$ ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW *±1 mm on each measurement, i.e.*

$R_f = 0.71 – 0.79$

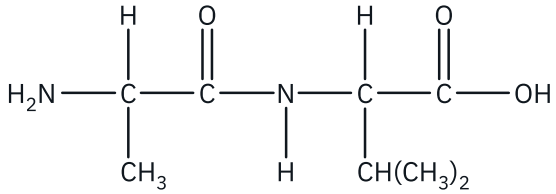
$R_f = 0.22 – 0.28$

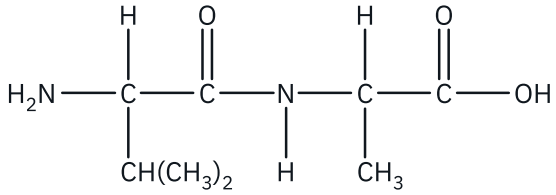
ALLOW *values that round to 2dp to give a value in the acceptable range*

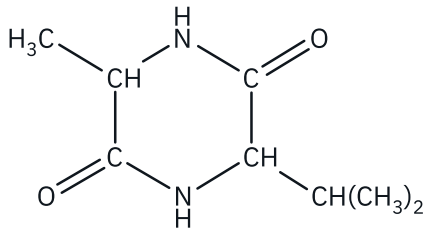
Working is not required

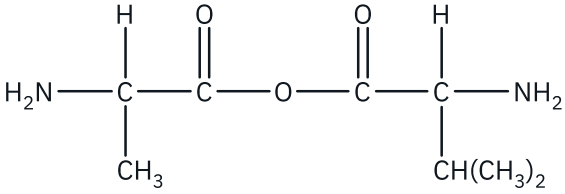
22(a)(ii)

Any 2 from the following: ✓✓









[2 marks]

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

IGNORE *connectivity*

Check structures carefully to ensure they are different from each other

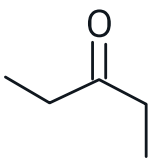
ALLOW ECF *from wrong R_f values in 22a(i)*

R group should be consistent with R_f values however **ALLOW ECF** if incorrect R group is repeated in second structure

ALLOW ECF *for one small slip e.g. missing H on NH group*

22(b)(i)

Pentan-3-one



✓

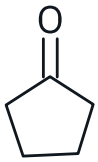
Cyclopentanone

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

IGNORE *non-organic products e.g. CO_2,*

O=C=O

, H_2O etc



✓

[2 marks]

22(b)(ii)

Mark is for a clear description of the relative positions of the C=O/ketone and carboxylic acid/COOH in alpha and beta keto acids

Alpha-keto acids:

ketone/C=O is adjacent/next/bonded to carboxylic acid/COOH

AND

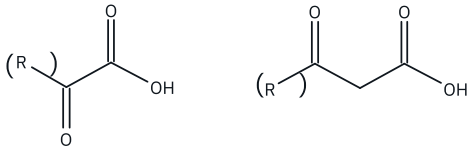
Beta-keto acids:

ketone/C=O two carbons away from carboxylic acid/COOH ✓

OWTTE

[1 mark]

ALLOW *labelled structures e.g.*



Alpha-keto acids:

ALLOW *ketone/C=O is on the adjacent C to the carboxylic acid//COOH (matches alpha amino acid description)*

ALLOW *Bonded to the same C*

Beta-keto acids:

ALLOW *ketone/C=O on 3rd carbon (from COOH)*

ALLOW *has carbon in-between functional groups*

IGNORE *bonded to different C (must be specific)*

Alternative approach – comparison of decomposition

ALLOW *alpha keto acids decompose to form an aldehyde and beta keto acids form a ketone OWTTE*

Q73 · Chromatography and functional group tests · [1 mark]

Answer: **A**

1, 2 and 3

Q74 · Chromatography and functional group tests · [1 mark]

Answer: **A**

0.25

Q75 · NMR spectroscopy · [1 mark]

Answer: **C**

OCR MARK SCHEME

3

EXAMINER GUIDANCE

ALLOW *3 (This is the number of peaks in the NMR spectrum)*

Q76 · NMR spectroscopy · [9 marks]

OCR MARK SCHEME

20(a)

Empirical formula

Mole Ratio C : H : O = 5.88 : 5.92 : 1.47 ✓

Empirical formula = C_4H_4O ✓

Molecular formula

Molecular formula = $C_8H_8O_2$

AND

Evidence of 136 in working or from labelled peak in spectrum ✓

[3 marks]

EXAMINER GUIDANCE

ALLOW $\frac{70.58}{12.0} : \frac{5.92}{1.0} : \frac{23.50}{16.0}$

ALLOW *4:4:1 if linked to C:H:O*

Alternative method for 3 marks:

C: $\frac{136 \times 70.58/100}{12.0} = 8$

H: $\frac{136 \times 5.92/100}{1.0} = 8$

O: $\frac{136 \times 23.50/100}{16.0} = 2$

20(b)

Functional groups

Phenol **AND** ketone ✓

Explanation

Links phenol to (weak) acidity

AND

no reaction with Na_2CO_3 (so not carboxylic acid) ✓

Links 2,4-DNP(H) or Brady's reagent observation to carbonyl

AND

Tollens' reagent observation (so not an aldehyde) ✓

[3 marks]

DO NOT ALLOW *any other functional groups for first marking point.*

ALLOW *identity of functional groups in the explanation if not stated on functional group prompt line.*

ALLOW *"aldehyde or ketone" in place of carbonyl*

20(c)

Carbon NMR analysis

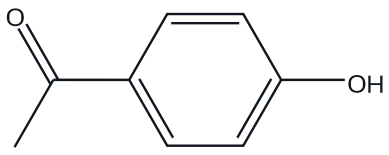
Peaks between 110–160 ppm are the (four) aromatic (carbon environments) ✓

Compound contains a C=O between 190 - 200 ppm

AND

Compound contains a C-C at 20-30 ppm ✓

Structure



✓

[3 marks]

ALLOW *peaks to be identified by:*

- Peaks labelled on spectrum
- Peaks indicated on a chemical structure
- Peaks indicated from within text

Note: If identifying aromatic peaks from the spectrum all four peaks should be indicated.

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

Q77 · NMR spectroscopy · [1 mark]

Answer: **A**

$Si(CH_3)_4$

Q78 · NMR spectroscopy · [18 marks]

OCR MARK SCHEME

22(a)

$C_7H_{16} + 7½O_2 \rightarrow 7CO + 8H_2O$

OR

$C_7H_{16} + 4O_2 \rightarrow 7C + 8H_2O$ ✓

[1 mark]

EXAMINER GUIDANCE

ALLOW *multiples*

IGNORE *state symbols*

ALLOW *equations for incomplete combustion that give CO and/or C with* CO_2

e.g $C_7H_{16} + 9O_2 \rightarrow 4CO + 3CO_2 + 8H_2O$

$C_7H_{16} + 6O_2 \rightarrow 4CO + 3C + 8H_2O$

22(b)

Heptane compared to hexane

heptane (has a longer chain so) has more points of contact / more surface interaction (between molecules) ✓

heptane has stronger/more induced dipole(–dipole) interactions ✓

Pentan-1-ol compared to heptane and/or hexane

pentan-1-ol has hydrogen bonds that are strong(er than induced dipole –dipole interactions)

OR

(alcohols have) hydrogen bonds and induced dipole(-dipole) interactions/London forces ✓

Energy required to break forces

More energy is required to break induced dipole(–dipole) interactions in heptane than hexane

OR

More energy is required to break hydrogen bonds ✓

[4 marks]

ALLOW ORA *throughout*

ALLOW *heptane has more electrons*

IGNORE *IDID*

ALLOW *stronger/more London forces*

IGNORE *van der Waals' forces/VDW for induced dipole– dipole interactions (ambiguous as this term refers to both permanent dipole–dipole interactions and induced dipole–dipole interactions)*

IGNORE *'pentan-1-ol can form hydrogen bonds with water'*

ALLOW *'more energy to break intermolecular forces' if intermolecular forces are not stated.*

IGNORE *it is harder to break the intermolecular forces no reference to energy)*

IGNORE *more energy needed to separate molecules*

IGNORE *more energy is needed to break bonds*

22(c)(i)

$n(CO_2) = \frac{2.97}{44} = 0.0675$ (mol) ✓

$n(H_2O) = \frac{1.62}{18} = 0.0900$ (mol) ✓

Ratio of C : H

3 : 8 ✓

Molecular formula

$C_3H_8O_2$ ✓

Structure

any correct structure of $C_3H_8O_2$ ✓

e.g.

IGNORE *ratio of* CO_2 *to* H_2O *is 3:4*

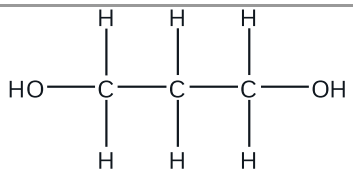
ALLOW *this mark from the correct molecular formula*

OR a correct structure if not shown in working

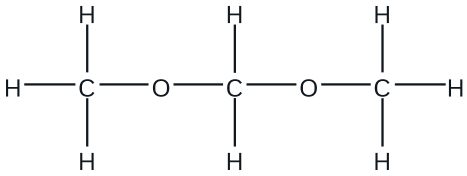
DO NOT ALLOW *an incorrect molecular formula*

Mark independently from molecular formula but structure MUST contain 3C, 8H and 2O

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*



OR



etc

[5 marks]

__ALLOW any__ vertical bond to the OH group

e.g. **ALLOW**

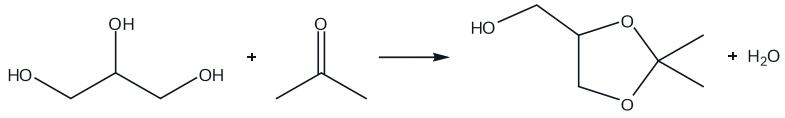


OR



__DO NOT ALLOW__ OH–

22(c)(ii)



Carbonyl compound identified as propanone ✓

Rest of equation ✓

[2 marks]

__ALLOW__ any combination of skeletal __OR__ structural __OR__ displayed formula as long as unambiguous

22(d)

Level 3 (5–6 marks)

Compound is a structure of $C_6H_{12}O_3$ that is consistent with splitting pattern and chemical shifts in NMR spectrum.

AND

Comprehensive reasoning with most of the data analysed.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Compound has a feasible chemical structure that is consistent with the splitting pattern in NMR spectrum but may have incorrect molecular formula.

AND

Reasoning provided with some of the data analysed.

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Correct determination of empirical formula and/or molecular formula.

OR

Analyses most of the NMR data.

OR

Indicative scientific points:

Empirical and Molecular Formula

- $C : H : O = \frac{54.54}{12} : \frac{9.10}{1} : \frac{36.36}{16}$

4.545 : 9.10 : 2.273

2 : 4 : 1

- Empirical formula = C_2H_4O
- uses m/z = 132.0 to determine molecular formula as $C_6H_{12}O_3$

^{1}H NMR analysis

Spectrum:

- δ = 4.0 ppm, quartet, 1H, CH_3–CH–O
- δ = 1.3 ppm, singlet, 6H, $(CH_3)_2$–C
- δ = 1.2 ppm, doublet, 3H, CH_3–CH–

Without D_2O:

- Peak at 11.0 ppm COOH or OH
- peak at 3.6 ppm OH

Note: Data Sheet shows O-H chemical shift can occur around 11.0 ppm

Structure

Attempts to determine empirical and/or molecular formula **AND** analyses some of the NMR data.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

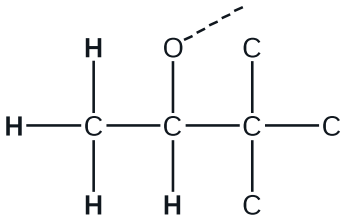
[6 marks]

***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

Contains

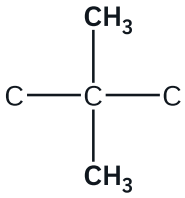
- region that gives doublet and quartet

e.g.

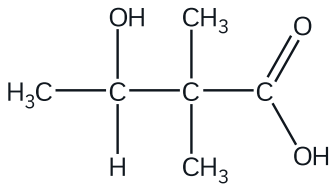


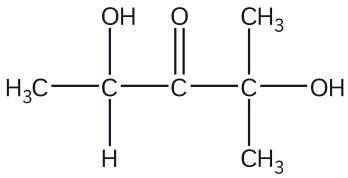
- region that gives singlet

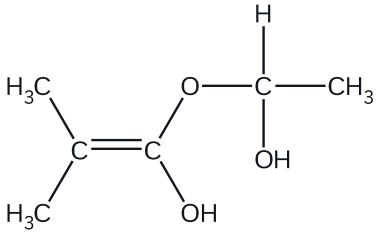
e.g.

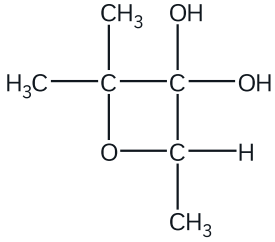


Examples of structures consistent with splitting and chemical shift in NMR









Note: there may be other possible structures that are consistent with the splitting pattern and chemical shifts in NMR

Q79 · NMR spectroscopy · [1 mark]

Answer: **B**

OCR MARK SCHEME

4

EXAMINER GUIDANCE

***ALLOW** 4 (This is the number of peaks in the NMR spectrum)*

Q80 · NMR spectroscopy · [1 mark]

Answer: **B**

Q81 · NMR spectroscopy · [1 mark]

Answer: **C**

2-Methylpropan-1-ol

Q82 · NMR spectroscopy · [22 marks]

OCR MARK SCHEME

18(a)(i)

ethyl 3-bromopropanoate ✓

[1 mark]

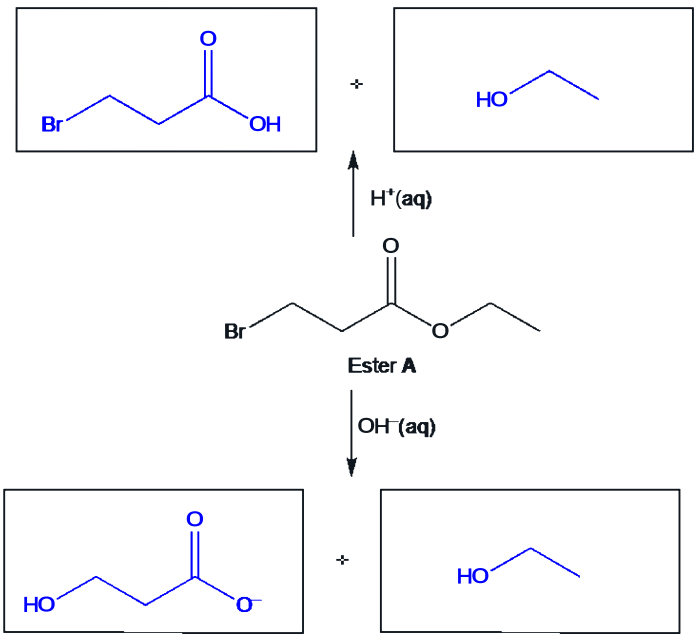
EXAMINER GUIDANCE

***ALLOW** one word: ethyl3-bromopropanoate*

OR more words, e.g. ethyl 3-bromo propanoate

***IGNORE** lack of hyphens, or addition of commas*

18(a)(ii)



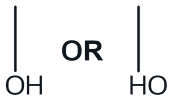
✓✓✓✓✓

***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

***ALLOW** in either order*

***ALLOW** any vertical bond to the OH group*

e.g. **ALLOW**



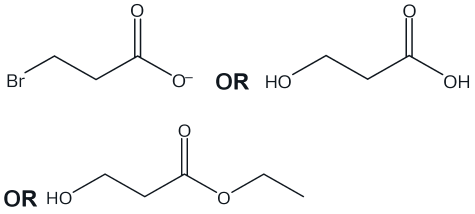
***DO NOT ALLOW** OH–*

***ALLOW** in either order*

For reaction with OH^-,

***ALLOW** one mark for*

[5 marks]



18(a)(iii)

hydrolysis ✓

IGNORE *'acid' and 'alkaline''*

IGNORE *nucleophilic substitution*

[1 mark]

18(b)

Proton environment	Chemical shift	Splitting pattern
1	3.0–4.3	Triplet
2	2.0–3.0	Triplet
3	3.0–4.3	Quartet
4	0.5–1.9	Triplet

Mark by column

Chemical shift: all 4 correct ✓✓

3 correct ✓

Splitting pattern: all 4 correct ✓✓

3 correct ✓

ALLOW *δ values ± 0.2 ppm, as a range or a value within the range*

ALLOW *integers for δ values*

e.g. 2 is equivalent to 2.0

ALLOW *quadruplet for quartet*

ALLOW *diagrams to show splitting pattern*

e.g.



for triplet



for quartet

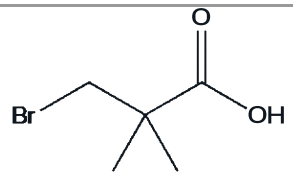
ALLOW *splitting patterns shown as numbers*

i.e. '3' for triplet, '4' for quartet

[4 marks]

18(c)

ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*



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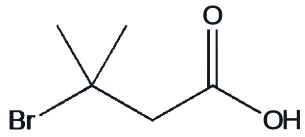

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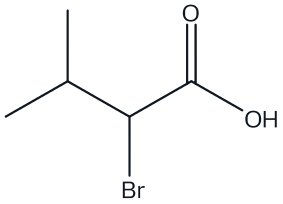


✓

[1 mark]

18(d)

***IF** answer on answer line = 24018, AWARD 2 marks*

***IF** answer on answer line = 27600, AWARD 1 mark*

Relative mass of 200 molecules = 200 × 138 = 27600 ✓

M_r of polyester = 27600 – 199 × 18 = 24018 ✓

[2 marks]

***ALLOW ECF** from incorrect M_r*

Alternative method based on repeat unit:

M_r of 200 repeat units = 200 x 120 = 24000 ✓

M_r of polymer = 24000 + 1 + 17 = 24018 ✓

18(e)(i)

Level 3 (5-6 marks)

Correct calculation of the mass of $(CH_3)_2CHCHO$.

AND

Planned synthesis includes oxidation of aldehyde and formation of ester C with most of the reagents and conditions identified and equations are mostly correct.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3-4 marks)

Calculation of the mass of $(CH_3)_2CHCHO$ is partly correct

AND

Planned synthesis includes oxidation of aldehyde and formation of ester C with some of the reagents and conditions identified

OR

Attempts to calculate mass of $(CH_3)_2CHCHO$ but makes little progress

Indicative scientific points may include:

Calculation of mass of $(CH_3)_2CHCHO$

Using moles

- $n(\text{ester}) = \dfrac{12.75}{102.0} = 0.125$ (mol)
- $n((CH_3)_2CHCHO) = \dfrac{0.125 \times 100}{40} = 0.3125$ (mol)
- Mass of $(CH_3)_2CHCHO = 72.0 \times 0.3125 = 22.5$ g

Using mass

- Theoretical mass of ester $= \dfrac{12.75 \times 100}{40} = 31.875$ (g)
- Theoretical $n((CH_3)_2CHCHO) = \dfrac{31.875}{102} = 0.3125$ (mol)

AND

Planned synthesis includes oxidation of aldehyde and formation of ester C with most of the reagents and conditions identified and equations for each step are mostly correct

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1-2 marks)

Calculation of the mass of $(CH_3)_2CHCHO$ is partly correct

OR

Planned synthesis includes both steps with some of the reagents and conditions identified

OR

Attempts equations for both steps but these may contain errors

OR

Describes one step of the synthesis with reagents, conditions and equation mostly correct

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

[6 marks]

- Mass of $(CH_3)_2CHCHO$ = 72.0 × 0.3125 = 22.5 g

***ALLOW** small slip/rounding errors such as errors in M_r e.g. use of 71 instead of 72 for $(CH_3)_2CHCHO$*

Examples of partly correct calculations

Mass = 3.60 g from $\frac{0.125 \times 40}{100} \times 72$

(% yield inverted)

Mass = 9.00 g from 0.125 × 72

(% yield omitted)

Synthesis: reagents and conditions

Step 1: Oxidation of aldehyde $(CH_3)_2CHCHO$

- Reagents: $Cr_2O_7^{2-}/H^+$
- Conditions: reflux
- Equation: $(CH_3)_2CHCHO + [O] \rightarrow (CH_3)_2CHCOOH$

Step 2: Formation of ester C

- Reagents: methylpropanoic acid/$(CH_3)_2CHCOOH$ and methanol/CH_3OH
- Conditions: acid (catalyst) reflux/heat
- Equation: $(CH_3)_2CHCOOH + CH_3OH \rightarrow (CH_3)_2CHCOOCH_3 + H_2O$

***IGNORE** attempts to form methanol in synthesis*

18(e)(ii)

Y (43) = $(CH_3)_2CH^+$ ✓

Z (71) $(CH_3)_2CHCO^+$ ✓

If '+' charge is missing/incorrect but the structures of both fragments are correct, award one mark

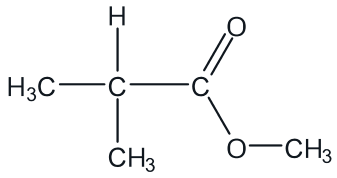
[2 marks]

***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

***ALLOW** positive charge to be anywhere on the structure*

For Y and Z,

***ALLOW** structure of a feasible fragment ion formed from ester C*



Ester C

e.g.

Y (43) = CH_3OC^+

Z (71) = $^+CCOOCH_3$

ALLOW *1 mark if both correct ions are shown but in the incorrect columns*

ALLOW *1 mark for both correct ions if one or both have an 'end bond'*

ALLOW *1 mark if both ions are shown using correct molecular formulae*

Q83 · NMR spectroscopy · [1 mark]

Answer: **A**

$CH_3CH_2COOCH_2CH_3$

Q84 · NMR spectroscopy · [1 mark]

Answer: **B**

Only 1 and 2

Q85 · NMR spectroscopy · [1 mark]

Answer: **C**

D_2O

Q86 · NMR spectroscopy · [6 marks]

OCR MARK SCHEME

23

Level 3 (5–6 marks)

Structure is either $CH_3CH_2COOCH_2C(CH_3)_3$ **OR** $(CH_3)_3CCH_2COOCH_2CH_3$

AND

Most of the data analysed.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Structure is an ester of $C_8H_{16}O_2$ with some key features present

AND

Analyses some of the data from at least 3 of the scientific points.

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Attempts analysis from at least 2 of the scientific points.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

EXAMINER GUIDANCE

Indicative scientific points:

1. Empirical Formulae

- $C : H : O = \frac{66.63}{12.0} : \frac{11.18}{1.0} : \frac{22.19}{16.0} = 5.55 : 11.18 : 1.39 = 4 : 8 : 1$
- Empirical formula = C_4H_8O

2. Molecular Formulae

- uses $m/z = 144.0$ to determine molecular formula as $C_8H_{16}O_2$

3. Functional group

From IR,

- → C=O from ~1740 cm^{-1}

IGNORE *references to C–O peaks*

No reaction with 2,4-DNP

- → no carbonyl/no ketone and aldehyde
- Likely to be an ester

No response or no response worthy of credit.

[6 marks]

4. ^{1}H NMR analysis

- δ = 0.9 ppm, singlet, 9H $-C(CH_3)_3$
- δ = 1.2 ppm, triplet, 3H CH_3CH_2-
- δ = 2.2 ppm, quartet, 2H CH_3CH_2CO
- δ = 4.1 ppm, singlet, 2H $-OCH_2-$

***ALLOW** approximate values for chemical shifts.*

Structure

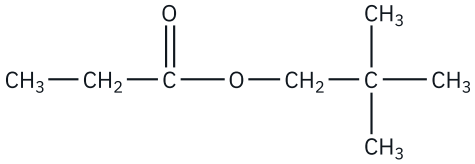
***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

Key features consistent with chemical shift data and relative peak areas

- $O\text{-}CH_2$
- $C(CH_3)_3$
- $CH_3CH_2C{=}O$

Correct Structure

- $CH_3CH_2COOCH_2C(CH_3)_3$



Q87 · NMR spectroscopy · [1 mark]

Answer: **C**

Q88 · NMR spectroscopy · [1 mark]

Answer: **B**

Only 1 and 2

Q89 · NMR spectroscopy · [6 marks]

OCR MARK SCHEME

24

Level 3 (5–6 marks)

Structure is $C_6H_5CHCH_3CHO$

AND

Analyses data from all 3 scientific points

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

EXAMINER GUIDANCE

Indicative scientific points:

1. Empirical (and Molecular) Formulae

- $C : H : O = \frac{80.60}{12.0} : \frac{7.46}{1.0} : \frac{11.94}{16.0} = 6.72 : 7.46 : 0.746 = 9 : 10 : 1$
- Empirical formula = $C_9H_{10}O$

2. Mass spectrum and IR

Structure with most key features including O atom(s)

AND

Analyses data from at least 2 of the scientific points

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Attempts analysis from at least 2 of the scientific points

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

[6 marks]

Mass spectrum

- uses $m/z = 134$ to give molecular formula: $C_9H_{10}O$
- Any possible fragments:

- m/z = 105 $C_6H_5CHCH_3^+$

- m/z = 77 $C_6H_5^+$

- m/z = 29 CHO^+

IR

- C=O from ~1700 cm^{-1}
- Likely to be aldehyde or ketone
- C=C (arenes) ~1500 cm^{-1}

ALLOW *Data Sheet ranges*

3. ^1H NMR

- δ = 1.4 ppm, doublet, 3H CH_3CH-
- δ = 3.8 ppm, quintet, 1H next to 4 adjacent H
- δ = 7.3 ppm, singlet, 5H C_6H_5-
- δ = 9.0 ppm, doublet, 1H -CHCHO

ALLOW *approximate values for chemical shifts*

Structure

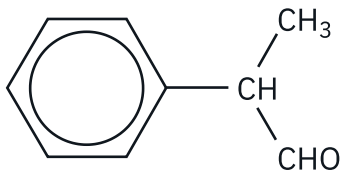
ALLOW *any combination of skeletal* ***OR*** *structural* ***OR*** *displayed formula as long as unambiguous*

ALLOW *correct Kekulé representation of benzene*

Key features

- Benzene ring
- C=O
- CH_3

Correct structure



- ($C_6H_5CHCH_3CHO$)

Aspects of the communication statement being met might typically include:

- Structures given are feasible and unambiguous

- Easy to follow layout on empirical formula calculation
- Empirical formula is shown to be same as molecular
- IR peaks linked clearly to bond it refers to not just functional groups
- Positive charge given on MS fragments
- MS fragments plausible for the molecular formula determined
- Clear information for each NMR peak
- No additional irrelevant/incorrect information given

Q90 · NMR spectroscopy · [1 mark]

Answer: **D**

Only 1

Q91 · NMR spectroscopy · [8 marks]

OCR MARK SCHEME

22(a)

$CDCl_3$ used as a solvent ✓

D_2O used to identify OH **OR** NH protons ✓

[2 marks]

EXAMINER GUIDANCE

Example and use required for each mark

ALLOW *for 1 mark, D_2O as a solvent*

22(b)

Level 3 (5–6 marks)

Structure I has a viable chemical structure of $C_6H_9NO_2$ which has the key features consistent with spectral data

AND

Most of the data analysed

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Compound I has a viable chemical structure of $C_6H_9NO_2$ with most of the key features consistent with spectral data

AND

Some of the spectral data analysed.

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Correct determination of empirical formula and/or molecular formula.

OR

Indicative scientific points:

Empirical and Molecular Formulae

C : H : N : O

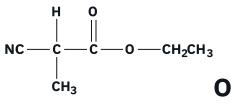
$= \frac{56.69}{12.0} : \frac{7.09}{1.0} : \frac{11.02}{14.0} : \frac{25.20}{16.0}$

OR 4.72 : 7.09 : 0.787 : 1.575

= 6 : 9 : 1 : 2

- Empirical formula = $C_6H_9NO_2$
- m/z = 127.0 and empirical formula mass (127) used to determine molecular formula as $C_6H_9NO_2$

Structures of compound I



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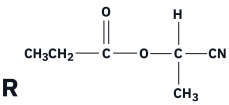

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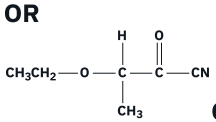

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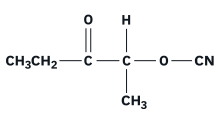


Analyses some of the IR and NMR data.

OR

Analyses most of the NMR data.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

[6 marks]

***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*

Key features

- C ≡N
- C=O in aldehyde, ketone, ester, amide, acid anhydride
- CH_3 group that would give a doublet
- CH_3 group that would give a triplet
- CH_2 group that would give a quartet

^{1}H NMR and IR analysis

^{1}H NMR spectrum

- δ = 4.2 ppm, quartet, 2H CH_3–CH_2–O
- δ = 2.9 ppm, quartet, 1H CO–CH–CH_3
- δ = 1.7 ppm, doublet, 3H CO–CH–CH_3
- δ = 1.3 ppm, triplet, 3H CH_3–CH_2

IR spectrum

- peak at 1750 (cm^{-1}) is C=O
- peak at 2280 (cm^{-1}) is C ≡N

***ALLOW** ranges from Data Sheet*

***IGNORE** references to C–O peaks*

Q92 · NMR spectroscopy · [1 mark]

Answer: **C**

Q93 · NMR spectroscopy · [1 mark]

Answer: **B**

Only 1 and 2

Q94 · NMR spectroscopy · [6 marks]

OCR MARK SCHEME

21

Level 3 (5–6 marks)

Compounds **D, E AND F** correctly identified

AND

Most of the observations and NMR data analysed.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)

Most of compounds D, E **AND** F correctly identified

AND

EXAMINER GUIDANCE

Indicative scientific points may include:

Observations from Test-tube tests

Some of the observations and NMR data analysed.

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)

Most of compounds D, E **AND** F correctly identified

OR

Some of compounds **D, E AND F** correctly identified

AND

Analyses some of the observations or NMR data

OR

Analyses most of the observations from the test-tube tests.

OR

Analyses most of the NMR data.

OR

Analyses some of the observations and NMR data

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

[6 marks]

2,4 DNP	**D** has no C=O
	E and **F** have C=O present
$H^+/Cr_2O_7^{2-}$	**D** is primary **OR** secondary alcohol
	E and **F** are ketones
	(negative test shows not aldehydes)
Br_2	**D**, **E** and **F** have no C=C/are saturated

^{13}C NMR analysis

D:

- 3 carbon environments/types of C
- δ = 24, 36 ppm C–C
- δ = 73 ppm, C–O

^{1}H NMR analysis

E:

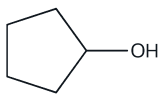
- δ = 2.4 ppm, quartet $CH_3–CH_2–C=O$
- δ = 1.1 ppm, triplet $CH_3–CH_2–$

F:

- δ = 2.6 ppm, heptet/multiplet $(CH_3)_2–CH–C=O$
- δ = 2.1 ppm, singlet, $CH_3–C=O$
- δ = 1.1 ppm, doublet $CH_3–CH–$

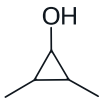
Structures

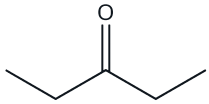
***ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous*



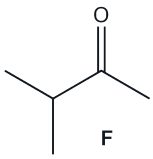
D

OR





E



F

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