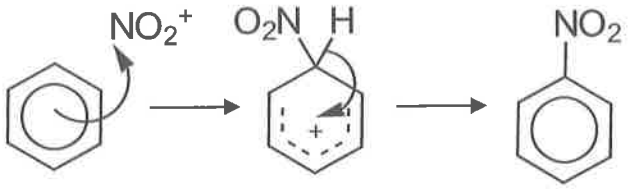
Section A

1	B	9	A
2	D	10	C
3	C	11	B
4	D	12	D
5	A	13	C
6	A	14	A
7	B	15	D
8	D		

Section B

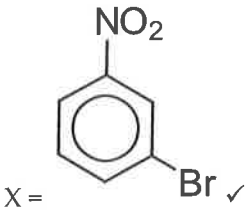
16 a) Overlap ✓ of the p orbitals ✓ (on the carbon atoms)

b) Generation of nitryl cation:
e.g. $H_2SO_4 + HNO_3 \rightarrow HSO_4^- + NO_2^+ + H_2O$ (ACCEPT $2H_2SO_4$ to give H_3O^+ OR two-step reaction via $H_2NO_3^+$) ✓



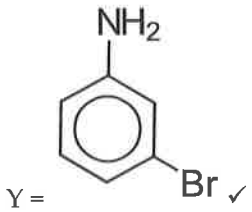
Correct arrow from ring to nitryl cation ✓
Correct intermediate with ring pointing in correct direction, and ending between the middle of the ring and carbons 2 and 5 ✓
Correct arrow to show loss of H^+, with arrow going into ring ✓
Regeneration of catalyst: $H^+ + HSO_4^- \rightarrow H_2SO_4$ ✓

c)



✓

(DO NOT ALLOW substitution at carbons 2 or 4)



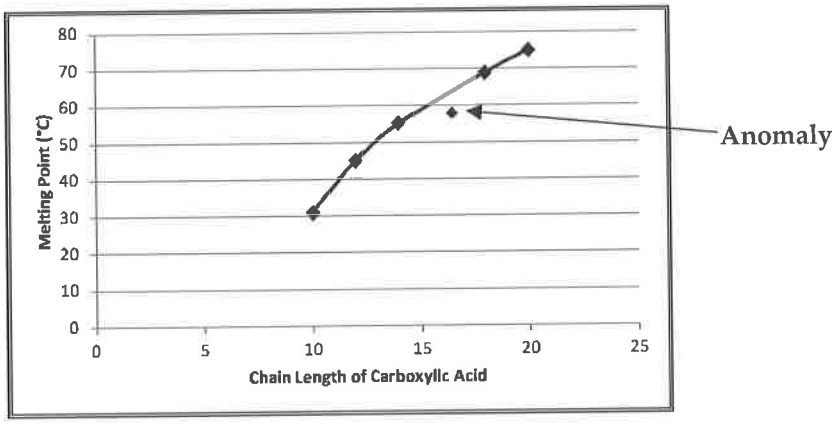
✓

(ALLOW ECF from incorrect location of Br in X)

d) i) 2,4,6-tribromophenylamine OR 2,4,6-tribromoaminobenzene ✓ (ALLOW any unambiguous name, provided 2,4,6- distribution of bromine groups included)

ii) The lone pair on nitrogen overlaps with the π system ✓
Resulting in increased electron density in the ring ✓
So it can induce a dipole in bromine molecules ✓

17 a i)



Axes labelled AND unit included on y-axis AND suitable scale chosen ✓
All points correct ✓
Suitable line of best fit AND anomaly correctly identified ✓

ii) Any value in range 60–63 °C ✓ (DO NOT ALLOW value without evidence of use of graph)

b i) Percentage uncertainty $= \frac{\text{Absolute uncertainty} \times \text{number of readings}}{\text{Measurement}} \times 100 = \frac{1 \times 1}{\text{Measurement}} \times 100$
A percentage uncertainty of 2 % means:
$2 = \frac{1 \times 1}{\text{Measurement}} \times 100$ so Measurement $= \frac{1 \times 1}{2} \times 100 = 50$ °C ✓
Experiments for chain lengths of 10 and 12 need to be repeated ✓

ii) Data logger ✓

c) As chain length increases there are more electrons AND therefore there are stronger induced dipole–dipole forces (ACCEPT London/dispersion forces) ✓
Therefore, more energy is needed to separate the molecules ✓
As chain length increases, adding extra carbons makes less difference (as a percentage); therefore, the graph begins to level off ✓

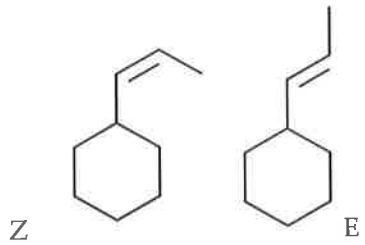
d) Any three of:
Recrystallise the acid ✓
Filter ✓
Take a melting point ✓
Compare to a database to identify it ✓

e) Solubility will decrease ✓
Alkyl chain is non-polar, and does not mix with water ✓ (ACCEPT is hydrophobic) ✓
Carboxlic acid / COOH group can form hydrogen bonds with water ✓
As the chain length increases, the attraction due to hydrogen bonding is increasingly outweighed by the insolubility of the alkyl chain ✓ (ALLOW AW, mark is for acknowledging that one outweighs the other as chain length increases)

18 a) They have the same molecular formula AND different structural formulae ✓

b) Electron pairs repel as far apart as possible ✓
The carbon in the double bond has three bonding regions around it (ACCEPT two bonding pairs and a bonding region) AND has a bond angle of 120° ✓
The other two carbons have four bonding pairs around them AND have a bond angle of 109.5° ✓

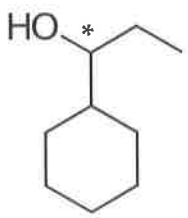
c)



Z E

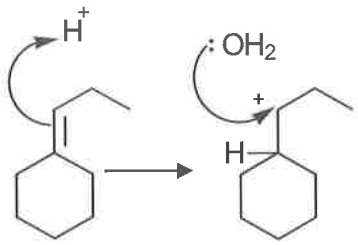
Two isomers ✓ correctly labelled as E and Z ✓

d) i) A carbon with four different groups attached to it ✓

ii)  ✓

e) i) Steam AND an acid catalyst ✓

ii) Electron pair acceptor ✓

iii) 

Correct arrow from double bond ✓ Correct intermediate (not necessary to show H) ✓ Correct arrow from lone pair on water to carbon / positive charge ✓

f) i) Addition can occur to add the OH group to the other end of the double bond (AW) ✓
Addition to form K is less favourable as it proceeds through a less stable intermediate ✓

ii) NB J and L have the same relative formula mass so it is not necessary to consider moles
Mass of J × 0.4 × 0.65 = 5.00 ✓
Mass of J = $\frac{5.00}{0.4 \times 0.65}$ = 19.2(3) g ✓

g) i) The stationary phase is the phase that does not move / is the solid that the solvent moves up ✓
The compounds dissolve in the mobile phase / adsorb to the stationary phase to different extents ✓
So the compounds travel different distances along the stationary phase in a given amount of time ✓
(ALLOW AW but answer must reference distance and a given time)

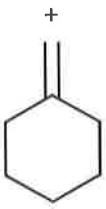
ii) $R_f = \frac{\text{Distance travelled by J}}{\text{Distance travelled by solvent}}$

$0.38 = \frac{\text{Distance travelled by J}}{3.9}$

Distance travelled by J = 0.38 × 3.9
= 1.5

Spot 1.5 cm above start point

h)



✓ (MUST have positive charge)
Can only be formed from J ✓

19 a)

LEVEL OF RESPONSE QUESTION	
Level 3: (5–6 marks)	Answer is structured in an entirely ordered manner. Tests are outlined to identify the presence of all three functional groups, with correct reagents and observations. At least two relevant safety precautions are included.
Level 2: (3–4 marks)	Answer is mostly structured in an ordered manner. Some correct details about identification of all three functional groups may be correct, with a few absences as well, or full accounts may be given for only two of the functional groups. At least one relevant safety precaution is included.
Level 1: (1–2 marks)	Answer has limited structure. Basic details about tests for two of the details are given (e.g. the reagents used) but complete sets of reagents and observations are not given. A mention of safety may be included, but may be vague or not entirely relevant.
0 marks	No creditworthy response.

Indicative Content

- (Warming with) Tollens' reagent allows identification of the aldehyde group
- Silver mirror/precipitate forms (ALLOW solid or ppt)

- 2,4-DNP can be used to identify ketone
- Yellow precipitate forms (ALLOW orange)
- But there is no reaction of the ketone with Tollens' reagent (ruling out aldehyde)

- Alcohol can be identified using acidified $K_2Cr_2O_7$ (ALLOW $Cr_2O_7^{2-}/H^+$)
- Colour change from orange to green
- But there is no reaction of the alcohol with Tollens' reagent (ruling out aldehyde)

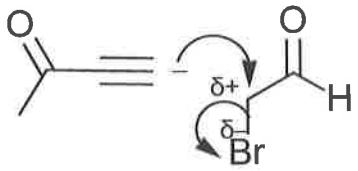
- Use water baths for warming/heating to ensure safety
- Place lids back on bottles and keep bottles away from naked flames (as they all have flammable vapours)
- Wash hands on contact / wipe down spillages immediately
- Wear goggles and lab coat

b) i) A broad peak in the 3200–3600 cm^{-1} range confirms the presence of the alcohol group ✓
But the ketone and aldehyde could not be distinguished from each other because they both have a peak 1630–1820 cm^{-1} ✓ (DO NOT ALLOW points without reference to the correct wavenumbers)

ii) Bonds in greenhouse gases / carbon dioxide and methane absorb infrared radiation ✓
They reemit this radiation back to Earth, preventing heat escaping / causing warming ✓
Acceptance of evidence to support this has prompted governments to change policies / favour renewable energy sources ✓

c) It is a redox reaction AND because bromine is reduced (from 0 to -1) AND because carbon is oxidised ✓
(IGNORE mention of specific oxidation states of carbon)

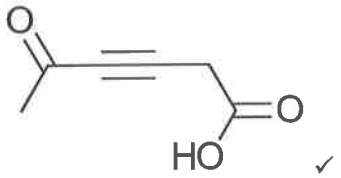
20 a)



✓✓ One mark for each correct arrow (Dipoles NOT required)

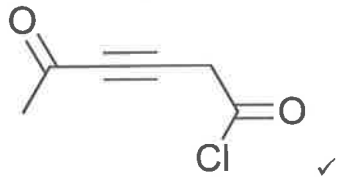
b) Reagents for P to Q: Acidified potassium dichromate OR $Cr_2O_7^{2-}$ / H^+ ✓
Reagents for Q to R: $SOCl_2$ ✓
Reagents for R to Ester 1: Phenol ✓

Compound Q



✓

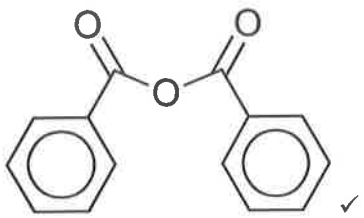
Compound R



✓

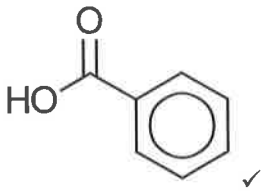
c) $CH_3COCCCH_2CHO + 2[H] \rightarrow CH_3COCCCH_2CH_2OH$
Correct structural formulae of organic reactant and product ✓ 2[H] ✓

d) i)



✓

ii)



✓

e) Separation using a separating funnel AND collection of the organic layer ✓
Use of a drying agent (to remove remaining water) ✓ (ACCEPT named drying agent, e.g. $MgSO_4$)
Redistillation AND collection of the ester as it distils off ✓

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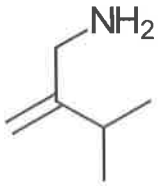
LEVEL OF RESPONSE QUESTION	
Level 3: (5–6 marks)	Answer is structured in an entirely ordered manner. Structure has been worked out correctly. At least three pieces of evidence stated, with at least one piece of evidence from the ^{13}C and ^{1}H.
Level 2: (3–4 marks)	Answer is mostly structured in an ordered manner. Suggested structure has some of the correct fragments and an M_r of 99. At least two pieces of evidence have been used correctly.
Level 1: (1–2 marks)	Answer has limited structure. At least two correct statements relating to the NMR have been made, and one correct fragment is deduced.
0 marks	No creditworthy response.

Indicative Content

Correct structure is:



^{1}H NMR

Shift	Splitting	Group
δ = 5.1	Singlet	$\underline{H}_2C=C$
δ = 2.9	Singlet	$C\underline{H}_2NH_2$
δ = 2.5	Singlet	$N\underline{H}_2$
δ = 1.8–1.9	Septet/multiplet	$C\underline{H}(CH_3)_2$
δ = 1.1–1.2	Doublet	$CH(C\underline{H}_3)_2$

^{13}C

- Five carbon environments
- Peaks at δ = 113 and δ = 126 due to C=C carbons
- Peak at δ = 48 due to C–N
- Peaks at δ = 20 and 30 due to C–C carbons

Other Evidence

- Disappearance of peak with integration of 2 at 2.5 in D_2O supports NH_2 group
- Five carbons and one nitrogen (and hydrogens) cannot add up to 99 – supports two carbons in the same environment
- Carbons in CH_3 groups of $CH(CH_3)_2$ in same environment

