Section A

Questions 1-3 : N/A

Question Number	Correct Answer	Mark
4	C	**1**

Question Number	Correct Answer	Mark
5	C	**1**

Question Number	Correct Answer	Mark
6	C	**1**

Question Number	Correct Answer	Mark
7	A	**1**

Question Number	Correct Answer	Mark
8	D	**1**

Question Number	Correct Answer	Mark
9	D	**1**

Question Number	Correct Answer	Mark
10	D	**1**

Question Number	Correct Answer	Mark
11	A	**1**

Question Number	Correct Answer	Mark
12	B	**1**

Question Number	Correct Answer	Mark
13	B	**1**

Question Number	Correct Answer	Mark
14	D	**1**

Question Number	Correct Answer	Mark
15	B	**1**

Question Number	Correct Answer	Mark
16	B	**1**

Question Number	Correct Answer	Mark
17	B	**1**

Question Number	Correct Answer	Mark
18	A	**1**

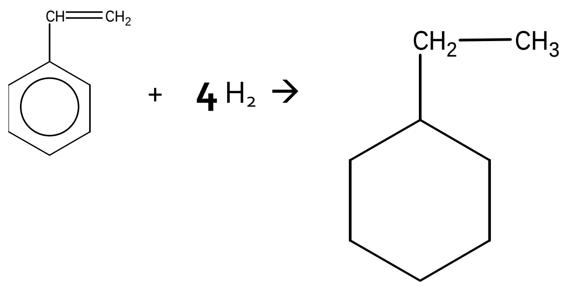
Question Number	Correct Answer	Mark
19	B	**1**

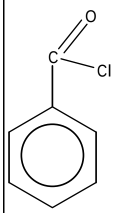
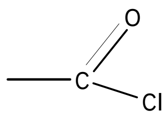
Question Number	Correct Answer	Mark
20	C	**1**

Question 21 : N/A

Question Number	Acceptable Answers	Reject	Mark
22(a)(i)	Addition / reduction / free-radical addition IGNORE references to ‘hydrogenation’	‘redox’ ‘electrophilic addition’ ‘nucleophilic addition’	**1**

Question Number	Acceptable Answers	Reject	Mark
22(a)(ii)	**First mark:** **Delocalization** (of π/p electrons in benzene ring) **(1)** IGNORE reference to ‘resonance’ **Second mark:** Results in more **energy** needed to **break** the **bonds** in benzene (compared with three separate π bonds) **(1)** ALLOW confers **stability** on the molecule / makes benzene **more stable** (than expected) IGNORE Reference to carbon-carbon bond lengths Values of any enthalpy changes Mark the two points independently		**2**

Question Number	Acceptable Answers	Reject	Mark
22(a)(iii)	 (ΔH =) **— 328** **(**kJ mol^{-1}) **First mark**: For “4” **Second mark**: Product as above / correct skeletal formula of product ALLOW Side chain written as $-C_2H_5$ **Third mark**: **—**328 (kJ mol^{-1}) **NOTE** **One** H_2 added showing a CQ correct product with only side chain reduced and cq ΔH = **—**120 **(**kJ mol^{-1}) scores **(2)** **Three** H_2 added showing a CQ correct product with only the benzene ring reduced and cq ΔH = **—**208 (kJ mol^{-1}) scores **(2)** **Five** H_2 added with fully correct product drawn and ΔH = **—**448 (kJ mol^{-1}) scores **(2)** **Three and a half** H_2 added showing a fully correct product and ΔH = **—**268/**—**293(.3)(kJ mol^{-1}) scores **(2)** **NOTE** Mark scoring points independently		**3**

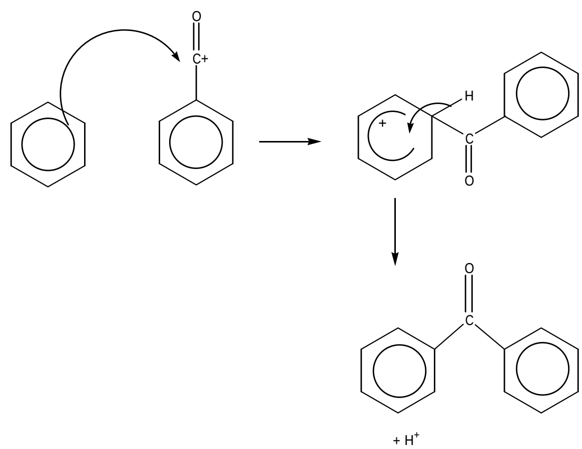
Question Number	Acceptable Answers	Reject	Mark
22(b)(i)	 Mark awarded for displaying 		**1**

Question Number	Acceptable Answers	Reject	Mark
22(b)(ii)	Electrophilic substitution **BOTH** words needed IGNORE references to ‘acylation’ and /or ‘Friedel-Crafts’		**1**

Question Number	Acceptable Answers	Reject	Mark
22(b)(iii)	Friedel **and** Crafts **BOTH** names are needed for this mark		**1**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>22(b)(iv)</td><td>First mark:
C_6H_5COCl + $AlCl_3$ → $C_6H_5CO^+$ + $AlCl_4^-$
(1)

+ can be anywhere on the C_6H_5CO in the equation for the first mark



($AlCl_4^-$ + H^+ → HCl + $AlCl_3$)
NOTE:
If ethanoyl chloride or any other acid chloride or the generic RCOCl is used instead of benzoyl chloride, no first mark can be awarded but the 2nd, 3rd and 4th marks can be awarded consequentially

Second mark: First curly arrow, as shown, to start from inside the hexagon to the correct C+ carbon (i.e. not to the benzene ring)
Note the + must be on the C of the C=O/CO for this mark
(1)
Third mark: Intermediate correctly drawn
(1)
NOTE
+ can be shown anywhere in the ring or at the C atom where electrophile is bonded.
The 'horseshoe' in the intermediate to cover at least three carbon atoms

Fourth mark: Second curly arrow as shown from C—H bond to reform the ring, not from the H atom in this bond
(1)
NOTE
Products do not have to be shown nor the equation for regeneration of the catalyst given</td><td></td><td>4</td></tr>
</table>

Question Number	Acceptable Answers	Reject	Mark
22(b)(v)	Absorbs / reflects / blocks / protects from / shields against / **uv** (light/ radiation) IGNORE 'non-toxic' / references to IR	**adsorbs** uv light	**1**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>22(c)(i)</td><td>Any TWO of the following

(1) for identifying the bond by formula as shown and (1) for wavenumber in each matching pair

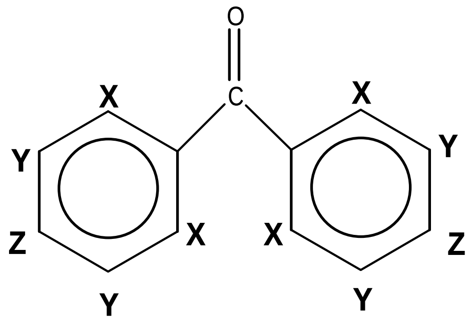
UNITS are not required

<table>
<tr><th>Bond</th><th>Wavenumber range/wavenumber (cm^{-1})</th></tr>
<tr><td>C=C</td><td>1600 / 1580 / 1500 / 1450
All four values needed</td></tr>
<tr><td>C=O</td><td>1700 – 1680</td></tr>
<tr><td>C-H</td><td>3030</td></tr>
<tr><td>C-H</td><td>750 / 700
Both values needed</td></tr>
</table>

NOTE
ALLOW
Correct wavenumber range, or any number within the correct range, for C=O

Mark identification of the bond and the wavenumber independently
(eg a correct bond with a wrong wavenumber, or vice-versa, scores one of the two marks in each case)

IGNORE
nmr values / chemical shifts</td><td></td><td>4</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>22(c)(ii)</td><td>

First mark

EITHER
Identifies correctly the three different proton environments

ALLOW
If the three different proton environments are only shown on one of the benzene rings

NOTE
On right-hand ring, clockwise from C=O, positions 2, 3 and 4
And /or 2,4 and 5 are shown as different environments
and /or
On left-hand ring, anti-clockwise from C=O, positions 2, 3 and 4
And /or 2,4 and 5 are shown as different environments

OR

Identifies proton Z correctly on both benzene rings (1)

Second mark
Fully correct labelling both rings using the letters X, Y and Z

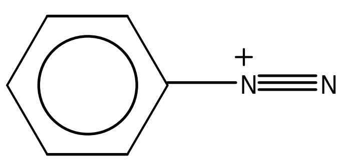
NOTE
X and Y labels are interchangeable, Z is not (1)</td><td></td><td>2</td></tr>
</table>

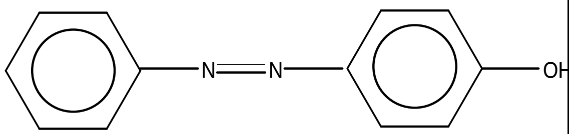
Total for Question 22 = 20 Marks

Question Number	Acceptable Answers	Reject	Mark
23(a)(i)	**Lone pair** (of electrons on the nitrogen atom) ALLOW non-bonded pair (of electrons on the nitrogen atom)	**Lone pairs** **Spare pair**	**1**

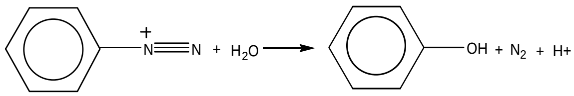
Question Number	Acceptable Answers	Reject	Mark
23(a)(ii)	**(with H_2SO_4)** $(C_4H_9NH_3^+)_2SO_4^{2-}$ **(1)** ALLOW $C_4H_9NH_3^+HSO_4^-$ **(with CH_3COOH)** $C_4H_9NH_3^+CH_3COO^-$ **(1)** **CHARGES** not essential Cation and anion can be in either order Max **(1)** if formula of the amine is incorrect in either case ALLOW (1) if only the correct cation is given in each case (i.e. the anion has been omitted in both cases) **NOTE** The correct ions can be shown separately Eg $(C_4H_9NH_3^+)_2$ **+** SO_4^{2-}		**2**

Question Number	Acceptable Answers	Reject	Mark
23(b)	Tin / Sn ALLOW Iron / Fe **(1)** (concentrated) **hydrochloric acid** **NOTE** If they write 'HCl', there must be some indication of concentrated Eg 'conc HCl' / 'concentrated HCl' ALLOW HCl(aq) (Followed by addition of alkali to liberate the free amine) **(1)** Mark the two points independently **NOTE** Do not allow 2nd mark if there is a suggestion that the acid and alkali are added together simultaneously	$LiAlH_4$ **Just 'HCl'** **'dilute'** hydrochloric acid / sulfuric acid	**2**

Question Number	Acceptable Answers	Reject	Mark
23(c)(i)	 **NOTE** If the above structure is drawn, the + charge must be on the N connected directly to the benzene ring ALLOW —N=N$^+$ on ring IGNORE Cl^-	N_2^+ on ring	**1**

Question Number	Acceptable Answers	Reject	Mark
23(c)(ii)			**1**

Question Number	Acceptable Answers	Reject	Mark
23(c)(iii)	**(Conditions)** (Presence of) NaOH / KOH / alkali /OH^- **(1)** ALLOW 'Alkaline (conditions)' or 'base' or 'high pH' IGNORE Any references to temperature **(Use)** Dye / pigment / colouring / indicator / in foodstuff / in paint / methyl orange **(1)** IGNORE Any reference to medicines		**2**

Question Number	Acceptable Answers	Reject	Mark
23 (d)	 ALLOW The +sign to be on either N atom in the benezenediazonium ion OR $C_6H_5N_2^+ + H_2O \rightarrow C_6H_5OH + N_2 + H^+$ OR $C_6H_5N_2Cl + H_2O \rightarrow C_6H_5OH + N_2 + HCl$ OR $C_6H_5N_2^+ + 2H_2O \rightarrow C_6H_5OH + N_2 + H_3O^+$ OR $C_6H_5N_2^+Cl^- + H_2O \rightarrow C_6H_5OH + N_2 + HCl$ **NOTE** —C_6H_5 can be written or drawn **First mark** for $\mathbf{N_2}$ **(1)** **Second mark** for rest of the equation correct **(1)** IGNORE State symbols, even if incorrect		**2**

Question Number	Acceptable Answers	Reject	Mark
23(e)(i)	(Otherwise) too much (product) remains in solution OR If excess (solvent) is used, crystals might not form ALLOW To avoid losing (too much) product (in the filtrate when crystallization occurs) / 'to maximize the yield'/ 'will crystallize better from a concentrated solution'/ 'will recrystallize (better) when cold' IGNORE References to a 'saturated solution' or references to 'dilution' or references to the time taken for crystals to form		**1**

Question Number	Acceptable Answers	Reject	Mark
23(e)(ii)	**(Insoluble impurities removed)** By **hot** filtration / During the **first** filtration / During the **second** step in the process **(1)** **(Soluble impurities removed)** By remaining in solution / Left in filtrate / Removed when washed (with cold solvent) **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
23(e)(iii)	Measure the melting temperature / melting point **and** compare with data / known value (from a data book / literature / Internet /data base) (BOTH points needed for the mark) OR The melting point is sharp (Just this statement is needed for the mark) ALLOW Any form of chromatography IGNORE References to any types of spectroscopy	**(0)** if reference to determination of the boiling point is made	**1**

Total for Question 23 = 15 Marks

Question Number	Acceptable Answers	Reject	Mark
24(a)(i)	$TiCl_4 + 4Na \rightarrow 4NaCl + Ti$ IGNORE State symbols, even if incorrect ALLOW Multiples Reversible arrows		**1**

Question Number	Acceptable Answers	Reject	Mark
24(a)(ii)	Ti **reduced** as oxidation number decreases from **+4 to 0**/ changes from **+4 to 0** **(1)** Na **oxidized** as oxidation number increases from **0 to +1** /changes from **0 to +1** **(1)** ALLOW Correct oxidation numbers only for one mark **NOTE** Max (1) if no + sign included ALLOW **'4+'** and/or **'1+'** given instead of **+4** and **+1** **NOTE** If any of the oxidation numbers are wrong, award max (1) for the idea that during oxidation the oxidation number increases **AND** during reduction the oxidation number decreases IGNORE References to loss and /or gain of electrons		**2**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>24(b)</td><td>(Ti [Ar]) $3d^2\ 4s^2$ / $4s^2\ 3d^2$
(1)

(Ti^{3+} [Ar]) $3d^1$ / $3d^1\ 4s^0$
(Ti^{4+} [Ar]) 'nil' / $3d^0\ 4s^0$ / $3d^0$
space left blank by candidate

BOTH Ti^{3+} and Ti^{4+} correct for second mark
(1)

Mark CQ on Ti electron configuration for the second mark

ALLOW
Upper case (e.g. 'D' for 'd' in electronic configurations)
Subscripts for numbers of electrons

Full correct electronic configurations $1s^2$, $2s^2$.....</td><td></td><td>2</td></tr>
</table>

Question Number	Acceptable Answers	Reject	Mark
24(c)(i)	**(d-block element)** **EITHER** Ti has (two) electrons in the 3d subshell / Ti has a partially filled d-subshell / Ti has a partially filled d-orbital / Ti has electrons in d-orbital(s) / Ti has electrons in d-subshell (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital **OR** (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital	**Outer / highest energy** electrons are in a d-orbital / **Outer / highest energy** electrons are in a d-subshell Electrons in the 'd-block'/ 'electrons in the d-shell'	**1**

Question Number	Acceptable Answers	Reject	Mark
24(c)(ii)	(transition element) Forms one (or more stable) **ions** / forms **Ti^{3+}** (ions) which have incomplete d-orbital(s) / an incomplete d-subshell / a partially filled d-subshell / an unpaired d electron IGNORE References to variable oxidation states		**1**

Question Number	Acceptable Answers	Reject	Mark
24(d)(i)	**First mark:** d-subshell splits /d-orbital**s** split (in energy by ligands) /d energy level(s) split(s) **(1)** **Second mark:** **absorbs light** (in visible region) **(1)** **Third mark:** Electron transitions from lower to higher energy / electron(s) jump from lower to higher energy OR Electron(s) promoted (within d) **(1)** Mark independently **NOTE** Maximum of (1) mark (i.e. the first mark only) if refers to electrons falling back down again	d-**orbital / **d-**shell** splits absorbs **purple** light	**3**

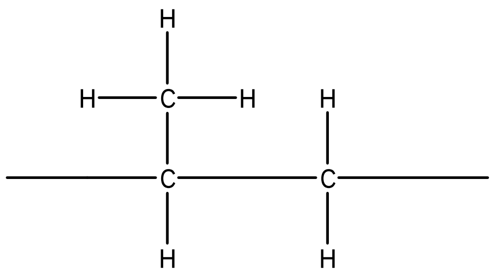
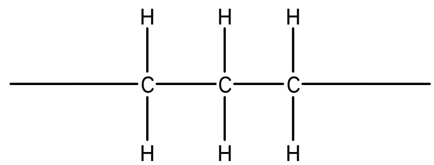
Question Number	Acceptable Answers	Reject	Mark
24(d)(ii)	No d-electrons / empty d-subshell		**1**

Question Number	Acceptable Answers	Reject	Mark
24(e)(i)	**TiO_2** **'Structure' mark** **EITHER** Giant (structure) **OR** Lattice (structure) IGNORE Whether stated as ionic or covalent for this mark **(1)** **TiO_2** **'Bonding' mark** EITHER **Strong** (electrostatic) attraction between ions ALLOW **Strong** ionic bonds / ionic bonds require a lot of energy to break **OR** **Strong** covalent bonds/covalent bonds require a lot of energy to break **(1)** **$TiCl_4$** **'Structure' mark** (Simple) molecules / (small) molecules **/**molecular **(1)** **$TiCl_4$** **'Bonding' mark** **Weak** London / dispersion / van der Waals' forces (between molecules) / London /dispersion / van der Waals' forces (between molecules) require little energy to break	TiO_2 (small) molecule**s** / simple molecular For TiO_2 mention of any type of intermolecular forces between molecules of TiO_2 $TiCl_4$ giant structure Covalent bonds broken (on melting) in $TiCl_4$ Ionic bonding in $TiCl_4$ Hydrogen bonding **(0)** for this mark	**4**

	NOTE If candidates assumes TiO_2 and $TiCl_4$ are both simple molecular, can score last mark for saying that the **named** intermolecular forces in TiO_2 are stronger that those in $TiCl_4$ IGNORE (Permanent) dipole-dipole forces **(1)** Mark the four scoring points independently		

Question Number	Acceptable Answers	Reject	Mark
24(e)(ii)	Amphoteric ALLOW Recognisable spellings		**1**

Question Number	Acceptable Answers	Reject	Mark
24(e)(iii)	$TiO_2 + 2H_2O + 2KOH \rightarrow K_2Ti(OH)_6$ OR $TiO_2 + 2H_2O + 2OH^- \rightarrow Ti(OH)_6^{2-}$ IGNORE state symbols even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
24(e)(iv)	 **MUST** have continuation bonds at each end ALLOW CH_3 IGNORE n and any brackets	 **Two** (or more) repeat units shown	**1**

Question Number	Acceptable Answers	Reject	Mark
24(f)(i)	(H_2O_2 + $2H^+$ +) **$2e^{(-)}$ → $2H_2O$** **BOTH** $2e^{(-)}$ **and 2**H_2O needed for the mark		**1**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>24(f)(ii)</td><td>(Moles H_2O_2 = $\frac{0.0200 \times 22.50}{1000}$
=) 4.5×10^{-4} mol H_2O_2
(1)

(Moles Ti^{3+} reacting in 25.0 cm^3) = 9.0×10^{-4} mol Ti^{3+}

(Moles Ti^{3+} in 250 cm^3) = 9.0×10^{-3} mol Ti^{3+}
(1)

(Original concentration of Ti^{3+}

= $\frac{9.0 \times 10^{-3}}{0.00500}$
=) 1.8 (mol dm^{-3})
(1)

1.8 (mol dm^{-3}) with or without working scores (3)

NOTES:
If mole ratio
H_2O_2 : Ti^{3+} is 1:1
final answer for concentration of Ti^{3+} is 0.9 (mol dm^{-3}) scores (2) overall

If mole ratio
H_2O_2 : Ti^{3+} is 2:1
final answer for concentration of Ti^{3+} is 0.45 (mol dm^{-3}) scores (2) overall

If candidate forgets to multiply no. of moles of Ti^{3+} by 10 then answer is 0.18 (moldm-3) this scores (2)

If volume of H_2O_2 used is 25.0 no first mark, but can score (2) if final answer CQ is 2(.0) (mol dm^{-3})</td><td></td><td>3</td></tr>
</table>

Question Number	Acceptable Answers	Reject	Mark
24 (f)(iii)	(It/titanium(III)/Ti^{3+}) **oxidized** (by oxygen in the air) ALLOW 'It is a **strong** reducing agent'	Hydrolysis	**1**

Question Number	Correct Answer	Mark
25	**D**	**1**

Question Number	Correct Answer	Mark
26	**B**	**1**

Question Number	Correct Answer	Mark
27	**A**	**1**

Question Number	Correct Answer	Mark
28 **(a)**	**C**	**1**

Question Number	Correct Answer	Mark
28 **b)**	**B**	**1**

Question Number	Correct Answer	Mark
28 **(c)**	**D**	**1**

Question Number	Correct Answer	Mark
29	**B**	**1**

Question Number	Correct Answer	Mark
30	**D**	**1**

Question Number	Correct Answer	Mark
31	**D**	**1**

Question Number	Correct Answer	Mark
32	**B**	**1**

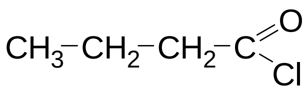
Question Number	Correct Answer	Mark
33	**A**	**1**

Question Number	Acceptable Answers	Reject	Mark
34 (a)(i)	(Acid) hydrolysis	substitution	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	$K_2Cr_2O_7$ / $Na_2Cr_2O_7$ / $Cr_2O_7^{2-}$ Potassium dichromate((VI)) / sodium dichromate((VI)) / dichromate((VI)) ions *ALLOW* manganate((VII)) ions, etc	Just “dichromate” chromates Correct formula with wrong name and vice versa Incorrect oxidation number	**1**

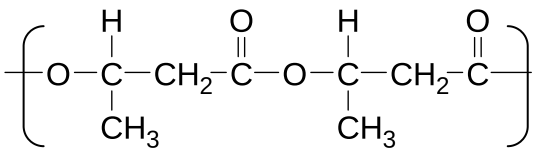
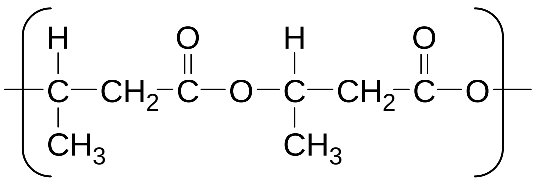
Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	Lithium tetrahydridoaluminate/ lithium aluminium hydride/ $LiAlH_4$ (in dry ether)	Just $[H^-]$	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	Methyl butanoate **(1)** $CH_3CH_2CH_2COOH + CH_3OH \rightarrow CH_3CH_2CH_2COOCH_3 + H_2O$ **(1)** *ALLOW* $\rightleftharpoons$ *IGNORE* state symbols even if wrong	Methyl butoate	**2**

Question Number	Acceptable Answers	Reject	Mark
34 (a)(v)	 Don't penalise undisplayed methyl groups as here. COCl must be displayed as above.	C_3H_7 for $CH_3CH_2CH_2$	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	Nitrogen inert / unreactive / less reactive (than oxygen) **OR** Oxygen might react with chemicals going through column / sample might oxidise		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Solubility (in liquid / stationary phase) **OR** Interaction with liquid / stationary phase **OR** Interaction between mobile and stationary phase **OR** Attraction for liquid / stationary phase **OR** **Strength** of (named) intermolecular forces **OR** Adsorption on liquid / stationary phase **OR** Absorption on liquid / stationary phase	Size of molecule / molar mass Polarity, unless with explanation Boiling point / volatility Viscosity Attraction for carrier gas Just a named intermolecular force Just 'retention time' Density	**1**

Question Number	Acceptable Answers	Reject	Mark
34 (c)(i)	 OR  Ester link including C=O **(1)** Rest of polymer with oxygens at end correct **(1)** All H atoms must be shown. *PENALISE* lack of displayed C=O once only *ACCEPT* Without brackets around formula but bonds at end should be shown More than two correct units *IGNORE* n after brackets		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	Hydrolysis **OR** Splits / breaks ester link **OR** polymer breaks down to monomers **OR** equation showing hydrolysis	Just ‘breaks polymer down’	**1**