



GCE MARKING SCHEME

**CHEMISTRY (NEW)
AS/Advanced**

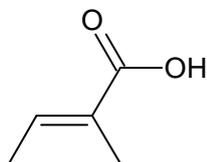
JANUARY 2010

CH4

SECTION A

1. (a) (i) Isomers whose atoms / groups take up different positions in space. [1]

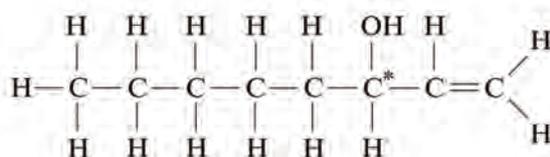
(ii)



[1]

(iii) Ethanol (1) in the presence of (concentrated) sulfuric acid / hydrogen chloride (acting as a catalyst). (1) [2]

(b) (i)



[1]

A carbon atoms that has four different groups / atoms bonded to it [1]

(ii) They rotate the plane of polarised light (in opposite directions) [1]

(iii) An equimolar / equal masses of the two enantiomers (1)

No (apparent) effect on the plane of polarised light (1) [2]

(c) (i) I Groups / atoms that are responsible for the absorption of (visible) light / giving colour [1]

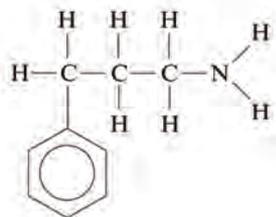
II It absorbs 'blue' light / all other colours of the visible spectrum /transmits orange [1]

(ii) The CH_2 protons 'see' three protons on the adjacent CH_3 group and by the $n+1$ rule are split into a quartet. (1)
The CH_3 protons 'see' two protons on the adjacent CH_2 group and by the $n+1$ rule are split into a triplet. (1) [2]

Total [13]

2. (a) (i) (Aqueous) sodium hydroxide – do not allow 'OH⁻' [1]
 (ii) Potassium / sodium cyanide – do not allow 'CN⁻' [1]
 (iii) Elimination / dehydration [1]

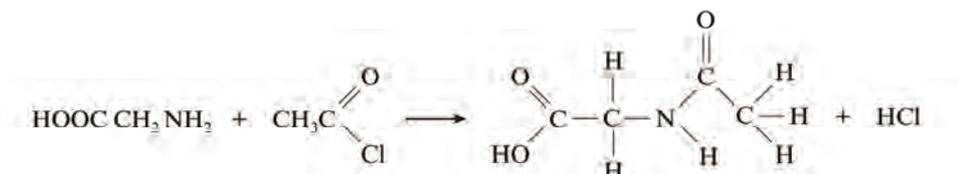
(iv)



[1]

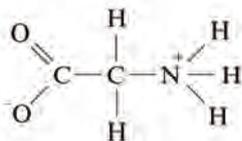
(b) Compound **T** (1); this has protons in only 'two' environments, ∴ 2 peaks (1) [2]

(c) (i)



balanced (1) correct displayed structure of ethanoyl derivative (1) [2]

(ii)



[1]

(d) The secondary structure results from hydrogen bonding (1). This occurs between the N – H and C = O groups of the polypeptide chain(s) (1) [2]

QWC Legibility of text; accuracy of spelling, punctuation and grammar; clarity of meaning. [1]

Total [12]

3. (a) (i) e.g. (Thorough) mixing of the solution [1]

(ii) Number of moles of

$$\text{NaOH} = \frac{26.25 \times 0.100}{1000} = 0.002625 / 2.625 \times 10^{-3} \quad (1)$$

Number of moles of CH_3COOH is also 0.002625 (1)

$$\begin{aligned} \text{Concentration of the diluted solution} \\ = \frac{1000 \times 0.002625}{25.00} = 0.105 \text{ mol dm}^{-3} \quad (1) \end{aligned}$$

$$\begin{aligned} \text{Concentration of the undiluted solution} \\ = 10 \times 0.105 = 1.05(0) \text{ mol dm}^{-3} \quad (1) \quad [4] \end{aligned}$$

(b) Conditions although the temperatures are the same / moderate, method 2 needs higher pressures (1) (or vice versa)

Yield / Products Method 1 gives a higher yield / Method 2 gives a lower yield (1)

Method 1 gives few or no co-products / Method 2 gives a number of co-products (1)

The atom economy of the naphtha method is low (1)

There will be problems of the separation of products if method 2 is used (1)

- maximum 4 marks [4]

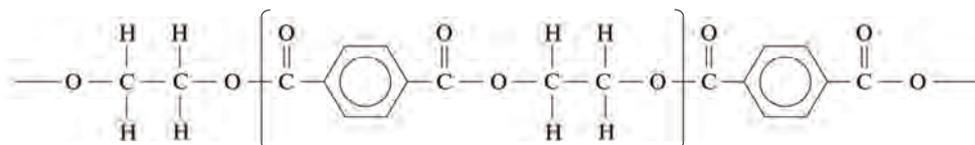
QWC Information organised clearly and coherently, using specialist vocabulary when appropriate [1]

(c)
$$\begin{array}{c} \text{CH}_3(\text{CH}_2)_{10}\text{COOCH}_2 \\ | \\ \text{CH}_3(\text{CH}_2)_{10}\text{COOCH} \\ | \\ \text{CH}_3(\text{CH}_2)_{10}\text{COOCH}_2 \end{array} \quad [1]$$

(d) ethyl palmitate is **c** (1)

$$\text{because } R_f = \frac{3.6}{6.0} = 0.60 \quad (1) \quad [2]$$

(e)



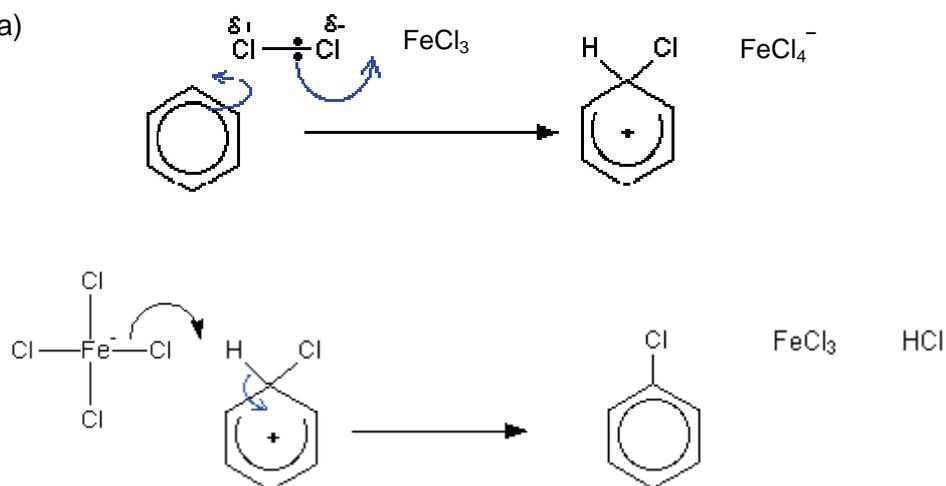
repeating unit (1) structure (1) [2]

Total [15]

Section A Total [40]

SECTION B

4. (a)



correct use of curly arrows (1)
 polarisation of chlorine (1)
 Wheland intermediate (1)
 mechanism shows loss of H^+ or HCl (1)

[4]

- (b) The chlorine lone pairs interact with the ring electrons (1)
 strengthening the C – Cl bond / decreasing the C – Cl bond polarity (1)
 making it less susceptible to nucleophilic attack (1) [3]
- (c) (i) 2-propylbenzene / 2-phenylpropane / cumene [1]
- (ii) Apart from phenol there is another product (1), the M_r of phenol and propanone are similar / OWTTE (1) [2]
- (iii) Propanone would give a peak at $\sim 1650 - 1750 \text{ cm}^{-1}$ (1)
 due to the C = O bond (1) [2]
- (iv) Purple colour / solution (1)
 Ethanol does not react with FeCl_3 solution / ethanol is a polar solvent and will dissolve phenol / ethanol does not react with phenol (1) [2]
- (v) An orange / red precipitate produced (1)
 Melting temperature taken (1) and compared with literature value (1) [3]
- (vi) $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ M_r 86 (1)
 CH_3CH_2^+ m/e 29 (1)
 $\text{CH}_3\text{CH}_2\text{CO}^+$ m/e 57 (1)

Total [20]

5. (a) (i)



accept one mole of ammonia as a reactant and one mole of HX as a product

- (ii) In the liquid phase butylamine molecules are attracted to each other (mainly) by hydrogen bonding (1). This is because the $-\text{NH}_2$ group is polar / correct mention of electronegativity / polarity shown in a diagram (1).
Attraction occurs between the nitrogen (lone pair) / (atom) of one molecule and the $\delta+$ hydrogen atom of another molecule (could be seen in a diagram) (1).
 \therefore stronger forces between molecules / more energy needed to separate molecules (and hence a higher boiling temperature). (1) [4]
- (iii) The indicator turns blue / purple (1). This is because butylamine / amines are basic (1), as the lone pair on the nitrogen atom is a proton acceptor / or nitrogen is an electron pair donor (could be seen on a diagram) (1). [3]

- (b) (i) 105 kg of ammonium butanoate gives 87 kg of butanamide
 \therefore 1 kg of ammonium butanoate gives $\frac{87}{105}$ kg of butanamide

$$\therefore 50.0 \text{ kg of ammonium butanoate gives } \frac{87 \times 50.0}{105} \text{ kg of butanamide} = 41.4 \text{ kg (1)}$$

$$\% \text{ yield} = \frac{26.9 \times 100}{41.4} \quad (1) = 65 \quad (1) \quad [3]$$

- (ii) I To see if the results are reproducible. [1]
II See if the reaction time can be reduced. [1]

- (c) (i) The (orange) mixture turns green (1) as the ethanol has reduced the acidified dichromate (to green Cr^{3+} (aq)). (1) [2]
- (ii) Ethanol gives a mixture of ethanal (1) and ethanoic acid (1).
The ethanal present will give a silver mirror with Tollens' reagent (1)
The ethanoic acid present will fizz / effervesce / produce CO_2 when sodium hydrogencarbonate or carbonate is added (1) [4]
(Accept responses based on Fehlings' / Benedict's reagents, acidified dichromate, 2,4-dinitrophenylhydrazine and iodoform test.)

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter [1]

Total [20]

Section B Total [40]



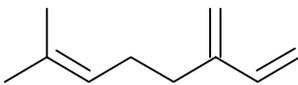
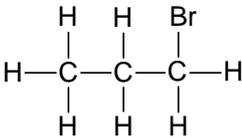
GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

SUMMER 2010

CH4

SECTION A

1. (a) (i) $C_{10}H_{16}$ (not shortened structural formula) [1]
- (ii)  [1]
- (iii) I Compound that contains no double bonds / single bonds only [1]
(Accept contains maximum number of hydrogens)
- II $C_{10}H_{16} + 3H_2 \longrightarrow C_{10}H_{22}$ [1]
(accept structural formulae, consequential from (a)(i))
- (iv) Moles $H_2 = \frac{8.96}{22.4} = 0.4$ [1]
4 double bonds [1]
- (b) (i) Ethane (accept formula) [1]
- (ii) $LiAlH_4$ [1]
- (iii)  [1]
- (iv) (1-)Propyl ethanoate [1]

Total [10]

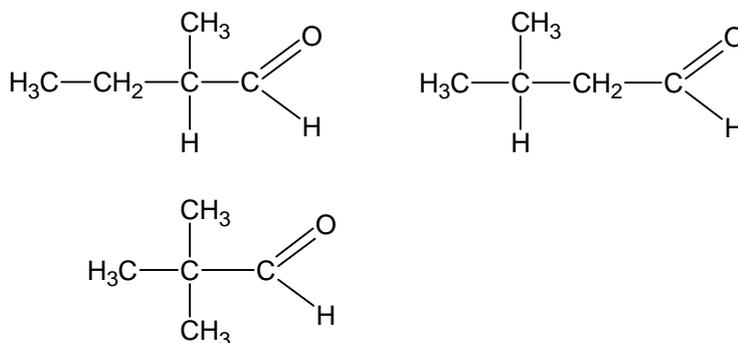
2. (a) In primary alcohols the –OH group is joined to a carbon atom bonded to two hydrogen atoms, in secondary alcohols the carbon atom is bonded to only one hydrogen. [1]

(b)	C	H	O	
	$\frac{68.1}{12}$	$\frac{13.7}{1.01}$	$\frac{18.2}{16}$	
	5.675	13.56	1.1375	[1]
	4.99	11.92	1	

Empirical formula = C₅H₁₂O [1]

Formula mass, 88.1(2), is same as M_r , therefore molecular formula is C₅H₁₂O [1]

- (c) (i) [1]



any one of three isomers

- (ii) I C [1]

- II [1]



- (iii) Add Tollens' reagent / Fehling's solution [1]

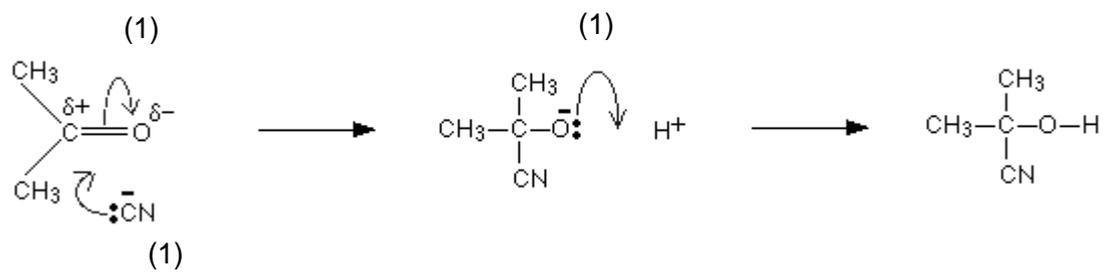
A no reaction, **B** gives silver mirror / red ppt. [1]

- (iv) Add iodine in aqueous sodium hydroxide / KI and NaOCl [1]

C no reaction, **D** gives pale yellow ppt. [1]

(d) (i) Nucleophilic addition [1]

(ii) [3]



Total [15]

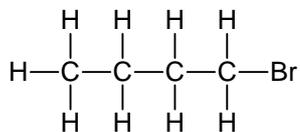
3. (a) Iron(III) chloride / bromine water [1]
Purple solution / white precipitate [1]
- (b) In phenol anion formed is stabilised by delocalisation of the negative charge over the benzene ring (1)
In alcohol anion formed is not stabilised by delocalisation (1)
In carboxylic acids anion formed is stabilised by delocalisation of the negative charge over the two oxygen atoms (1)
Delocalisation is stronger in acid than in phenol (1)
Phenol loses H⁺ more easily than alcohol and carboxylic acid does so more easily than phenol (1)
(Accept diagrams)
max 4 marks [4]
- (c) 4-chloro-3,5-dimethylphenol [1]
- (d) Atom economy = $\frac{94.06 \times 100}{122.07}$ [1]
= 77% [1]
- (e) [1]
- $$\begin{array}{ccccccccc} & & \text{O} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{O} & & \\ & & // & & | & & | & & | & & | & & // & & \\ \text{H}-\text{O} & - & \text{C} & - & \text{O}-\text{H} \\ & & \backslash & & | & & | & & | & & | & & \backslash & & \\ & & \text{O} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{O} & & \end{array}$$
- (f) Hexane-1,6-diamine / 1,6-diaminohexane [1]
- (g) [1]
- $$\left[\begin{array}{c} \text{O} & \text{O} \\ || & || \\ \text{---} \text{N}(\text{CH}_2)_6 \text{---} \text{N} \text{---} \text{C} \text{---} (\text{CH}_2)_4 \text{---} \text{C} \text{---} \\ | & | \\ \text{H} & \text{H} \end{array} \right]$$
- (h) In addition polymerisation only the polymer is formed [1]
(Accept description e.g. monomers join together with no water loss)
In condensation polymerisation the polymer and a small molecule are formed [1]
(Accept description e.g. water molecule lost as monomers join together)
(Accept for 1 mark only water is eliminated during condensation polymerisation but not during addition polymerisation)
- (i) Making aspirin / cellulose acetate / as an acylating agent [1]

Total [15]

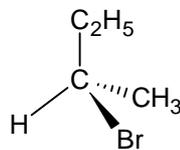
Total Section A [40]

SECTION B

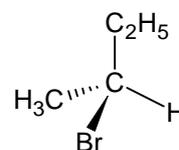
4. (a) (i) [3]



(1)



(1)



(1)

- (ii) Use a polarimeter to differentiate between isomers (1)
 One will rotate plane of plane polarised light to the right and one to the left / opposite directions (1)
 1-bromobutane will have no effect on plane polarised light (1) [3]

Accept use mass spectrometer / nmr spectroscopy to identify

1-bromobutane (1)

Answer gives peak present in 1-bromobutane that is not in other isomers (1)

(Accept converting to alcohols and carrying out iodoform test)

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

(b) (i) I $\text{C}_2\text{H}_5\text{Cl} + \text{NH}_3 \longrightarrow \text{C}_2\text{H}_5\text{NH}_2 + \text{HCl}$ [1]

II Nucleophilic substitution [1]

- (ii) Nitrobenzene (1)
 Tin and concentrated hydrochloric acid (1) [2]

- (iii) Sodium nitrite and hydrochloric acid, (1)
 under 5 °C (1)
 No change phenylamine, bubbles (of nitrogen) with ethylamine (1)

Accept alternative – bromine (1), aqueous (1), white ppt with phenylamine, no change with ethylamine (1)

[3]

5. (a) Planar molecule (1)
 each carbon bonded covalently to 2 other carbons and 1 hydrogen.(1)
 Sideways overlap of p-orbitals. (1)
 Leading to delocalised π – bonds. (1)
 above and below plane of molecule (1)
 (Maximum 4 marks for bonding)
- Alkenes have localised double bond /greater electron density /
 attract electrophiles more readily (1)
 In benzene stable delocalised system would be disturbed / has extra
 delocalisation energy / reacts by substitution (1) [6]
- QWC* Legibility of text; accuracy of spelling, punctuation and grammar,
 clarity of meaning (1)
 Selection of a form and style of writing appropriate to purpose and to
 complexity of subject matter (1) [2]
- (b) (i) Benzene is too hazardous / methylbenzoate is less toxic [1]
- (ii) The product is crude / impure [1]
- (iii) Add crystals to minimum amount of hot ethanol (1)
 Filter if necessary and leave to cool (1)
 Filter and dry (in air) (1) [3]
- (iv) Take a melting point and compare it with a book value [1]
- (v) $\frac{2.75}{1.1} = 2.5 \text{ cm}^3$ [1]
- (vi) Moles methylbenzoate = $\frac{2.75}{136} = 0.0202$ (1)
- Moles methyl 3-nitrobenzoate = $\frac{270}{181} = 0.0149$ (1)
 % yield = 73.8 % (1) [3]
- (vii) I Electrophilic substitution [1]
- II NO_2^+ [1]

Total [20]

Total Section B [40]



GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

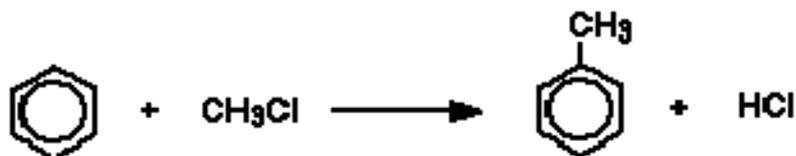
JANUARY 2011

CH4

SECTION A

1. (a) (i) $C_6H_5NO_2$ (1)
the blue light is absorbed / there is no yellow light to be reflected /
transmitted (1)
equivalent (1) [3]

- (b) (i)



[1]

- (ii) aluminium chloride / iron(III) chloride / correct formulae [1]

- (c) (i) The chlorine's (lone pair of) electrons interact with the ring π cloud of electrons (1)
making it less polar / stronger bond (1)
and therefore less susceptible to **nucleophilic** substitution (1) [3]

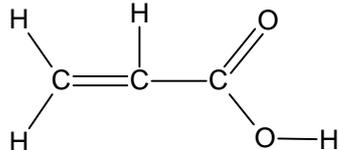
- (ii) Any TWO from
e.g. ease of manufacture / availability of starting materials /
percentage yield / shelf life of product / life of product in use /
effectiveness / suitability / range of colours [2]

- (d) (i) esters [1]

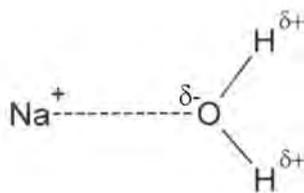
- (ii) reagents iodine / sodium hydroxide
OR sodium chlorate(I) / potassium iodide
 $I_2 / NaOH$ or OH^- $NaClO / ClO^- / KI / I^-$ (1)

- observation **yellow** precipitate / solid / crystals (1)
(antiseptic smell is a neutral answer) [2]

Total [13]

2. (a) (i) 3-bromopropene/3-bromoprop-1-ene [1]
- (ii) Reagent A (aqueous) sodium hydroxide / NaOH / OH⁻ (1)
 Reagent B potassium dichromate / K₂Cr₂O₇ / Cr₂O₇²⁻ (1) [2]
- (b) (i) condensation / (nucleophilic) addition – elimination [1]
- (ii) red / yellow / orange solid (a solid must be implied) [1]
- (iii) take its melting temperature, compare this with known values [1]
- (iv) Displayed formula  [1]
- Type of reaction oxidation / redox [1]
- (c) (i) Both carbon atoms of the double bond need to have different atoms / groups attached to them [1]
- (ii) Reagent iron(III) chloride / FeCl₃ OR aqueous bromine (1)
 Observation purple/blue/green colour white precipitate (1) [2]
- (iii) It is shown by compounds that have the same structural formula but where their bonds take up different positions in space [1]
- (do not accept descriptions of geometrical/optical isomerism)
- Total [12]

3. (a) (i) Chromophore [1]
- (ii)



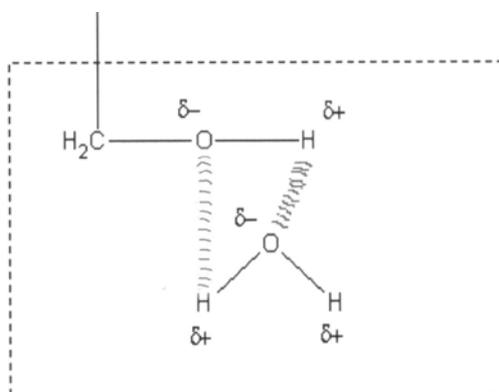
- The sodium ions are attracted to the δ^- oxygen atom of a water molecule [1]
- (iii) I 0 - 10 °C / <10°C [1]
- II (An ion that is) an electron **pair** acceptor / seeks out an electron rich site [1]
- (accept an electron deficient group/species)

- (b) (i) Brilliant Blue FF (1) as it has R_f value 0.80 and this has been identified on the chromatogram (1) [2]
must have the correct deduction, either 2 or 0 here

- (ii) Any TWO from e.g.
repeat the chromatography using a different solvent / take its visible spectrum and compare its λ_{max} with those of the two dyes / take its infrared spectrum and compare with the spectrum of the two dyes / take its NMR spectrum and compare its spectrum with the NMR spectrum of each individual dye (1), (1) [2]

- (c) $(\text{CH}_3\text{CH}_2\text{COO})_2\text{Ca} + \text{Ca}(\text{OH})_2 \rightarrow 2 \text{CaCO}_3 + 2 \text{C}_2\text{H}_6$
correct balancing (1) correct formula of ethane (1) [2]

- (d)

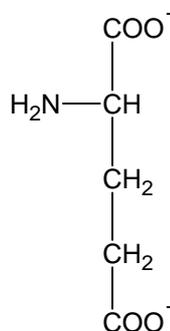


polarisation (1)

hydrogen bonding (1)

[2]

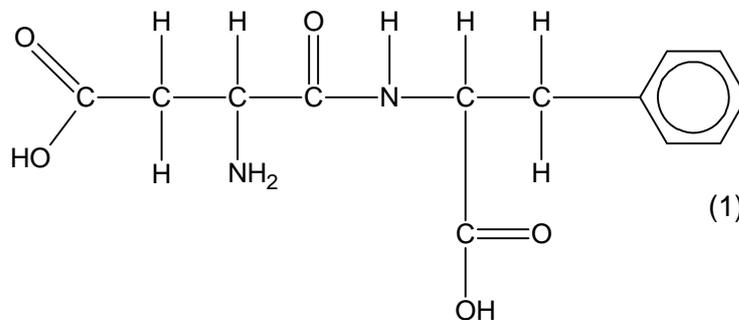
- (e)



accept the formula with Na^+ ions

[1]

- (f)



(1)

CH_3OH

(1)

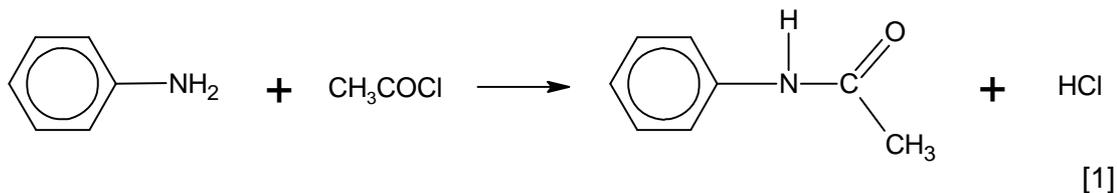
[2]

Total [15]

Section A Total [40]

SECTION B

4. (a) (i)



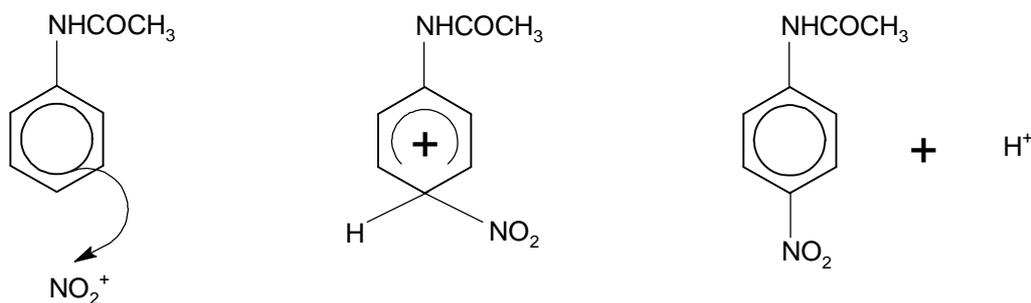
[1]

(ii) To remove **soluble** impurities [1]

(iii) The impure crystals are added to the **minimum** quantity of **hot water** / added to sufficient cold water and heated until all the crystals just dissolve / OWTTE (1) filter hot (1)
 Allow the mixture to cool (1)
 The product is then filtered (1) (washed) and dried in an oven at a **temperature <113 °C** / accept other drying methods that imply the temperature is <113 °C (1) [4]

QWC Information organised clearly and coherently, using specialist vocabulary when appropriate [1]

(b) (i)



(1)

(1) (Wheland) intermediate

(1) products

electrophilic substitution (1) [4]

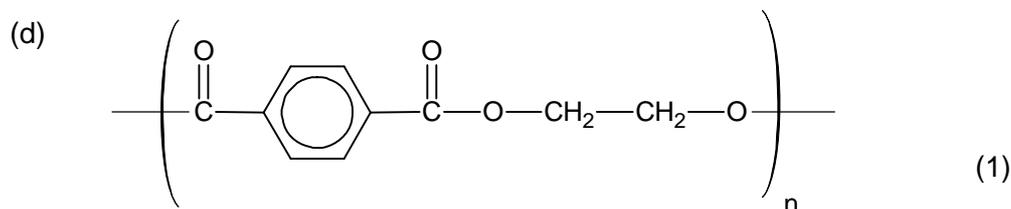
(ii) Since the 2-isomer is yellow (1) and the 4-isomer is colourless; when the 4-isomer is colourless / 'not yellow' then the 4-isomer is no longer contaminated (1) [2]

(iii) Moles of N-phenylethanamide = $\frac{8.10}{135} = 0.060$ (1)

Moles of the 4-isomer = $\frac{6.48}{180} = 0.036$ (1)

% Yield = $\frac{0.036 \times 100}{0.060} = 60.(0)$ (1) [3]

- (c) (i) Potassium manganate(VII) / permanganate / KMnO_4 [1]
(ii) To convert the (sodium) salt back to the (parent) acid [1]



in condensation polymerisation a small molecule / water is lost / produced (1)

[2]

Total [20]

5. (a) (i) Hydrogen cyanide ionises/dissociates (giving a hydrogen ion / H^+ and a cyanide ion / CN^-) (1)
(The mechanism is described as nucleophilic addition) because the CN^- ion acts as a nucleophile / base / electron pair donor (attacking (accept 'approaches') a δ^+ site) (1)
Electron density increases / negative charge produced on the oxygen atom (1)
This oxygen atom acts as an electron pair donor, attracting a hydrogen ion (1)
In effect a molecule of hydrogen cyanide has added across the carbon to oxygen double bond (1)
(Accept any four correct points) [4]
- QWC Legibility of text; accuracy of spelling, punctuation and grammar; clarity of meaning [1]
- (ii) Hydrolysis is a reaction with water (or a water containing reagent), where water 'splits' the 'organic molecule' (1)
In this reaction, hydrochloric / (dilute) sulfuric acid is used (1) [2]
- (b) (i) Number of moles of sodium hydroxide = $\frac{20.00 \times 0.250}{1000}$ = 0.005 (1)
Number of moles of lactic acid = 0.005
Mass of lactic acid = 0.005×90 = 0.45 g (1)
Percentage of lactic acid in the yoghurt = $\frac{0.45 \times 100}{50}$ = 0.90 (1) [3]
- (ii) It would produce a much smaller titre and this will lead to larger % errors - both statements required [1]
- (c) The dione does not react with Fehling's reagent (1)
The dial produces a brown solid (1) [2]

(d) Molecular formula must be $\frac{172}{43} = 4 \therefore C_8H_{12}O_4$ (1)

All oxygen atoms in ester group(s) - each ester group needs two oxygen atoms

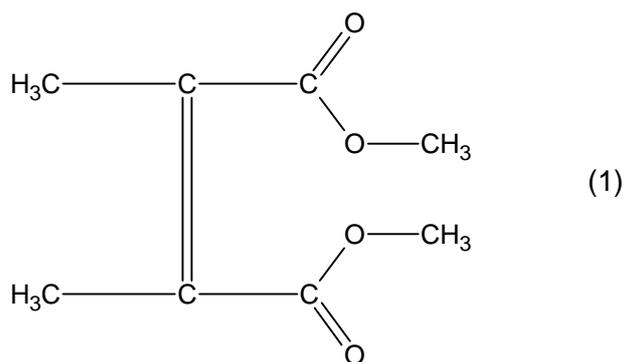
\therefore 2 ester groups (1)

Decolourises aqueous bromine $\therefore C=C$ (1)

Gives methanol as the only alcohol on hydrolysis \therefore methyl ester (1)

1H NMR suggests each signal \equiv 6 protons, 'remotely bonded' (1)

Ester is



[6]

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter [1]

Total [20]

Section B Total [40]



GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

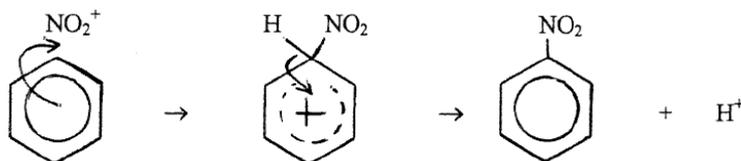
SUMMER 2011

CHEMISTRY - CH4

Q.1 (a) (i) Chromophore [1]

(ii) Yellow transmitted (or reflected) / other colours (e.g. blue and red) absorbed [1]

(b) (i)



(arrow must come from the bond)

[1]

(ii) $C_3H_2NO_2$ [1]

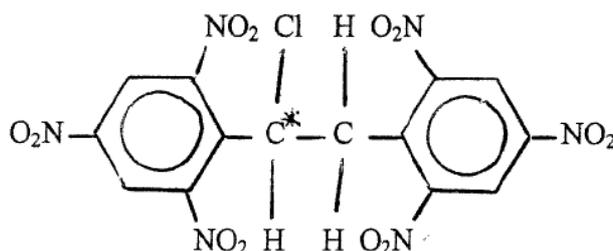
(iii) H_2SO_4 is losing a proton (to another species and becoming an HSO_4^- ion, acids are proton donors). [1]

(c) The benzene ring is more stable than an alkene because of its delocalised electron structure / π electron system / OWTTE (1)
If benzene underwent addition this would mean disrupting this stable electron system and this would require relative more energy / activation energy would be (much) higher. (1) [2]

QWC Legibility of text; accuracy of spelling, punctuation and grammar; clarity of meaning. [1]

(d) (i) There is no rotation about a double bond / each 'end' of the double bond has two different 'groups' attached to it [1]

(ii) I

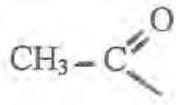


[1]

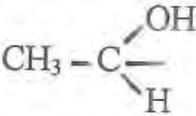
II They are mirror image forms (1) that rotate plane polarised light in opposite directions (1) [2]

III Elimination [1]

Total [13]

- Q.2** (a) (i) Sodium borohydride / sodium tetrahydridoborate(III) / lithium aluminium hydride / sodium and ethanol / zinc and ethanoic acid (accept correct formulae) [1]
- (ii) The absorption at $\sim 1700\text{ cm}^{-1}$ is due to the C = O bond (1)
As the reaction proceeds the intensity of this absorption becomes smaller because the butanal is being used up / butan-1-ol does not contain a C = O bond (1) [2]
- (b) (i) butan-1-ol > propanone > ethanol [1]
- (ii) Propanone [1]
- (iii) *Compounds* propanone / ethanol / propan-2-ol
Any two for one mark [1]
- Explanation* the compounds that give a positive iodoform test have to contain a
- 

or the



grouping
- [1]
- (iv) So that a valid comparison can be made between results from other teams / OWTTE [1]
(do not accept 'fair test')
- (c) There is a balance between the 'carbon' produced by burning and the 'carbon' absorbed by the plant (1)
When butan-1-ol is burnt carbon dioxide is produced, but this is used by plants / in photosynthesis to produce cellulose (1) [2]
- (d) (i) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{CH}_3\text{COOH} \rightarrow \text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$ [1]
accept $\text{C}_4\text{H}_9\text{OH}$ but not $\text{C}_4\text{H}_{10}\text{O}$ - functional groups must be present
- (ii) (concentrated) sulphuric acid / H_2SO_4 / hydrogen chloride (gas) / HCl(g) [1]
do not accept $\text{H}_2\text{SO}_4(\text{aq})$ / HCl

Total [12]

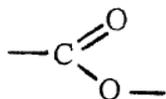
- Q.3** (a) (Free) radical [1]
- (b) $2\text{C}_3\text{H}_6 + 9\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$ [1]
- (c) (i) It is providing a pair of electrons to bond to a proton / acting as a lone pair donor / proton acceptor [1]
- (ii) I A process of boiling / evaporation and condensation without loss (of reactants) [1]
- II By using an electrical heater / or a suitable heating bath / heating mantle - do not accept 'water bath' [1]
- (d) Halothane would cause the most damage as it contains a weaker C-Cl / C-Br bond (1), which is broken in the upper atmosphere (1) (producing radicals that attack ozone).
Desflurane does not contain C-Cl / C-Br bonds, only the more stable C-F bonds. [2]
- (e) (i) Purple colour / solution / complex - do not accept 'precipitate' [1]
- (ii) I

Compound	Colour given with Universal Indicator paper	Reaction with sodium hydrogencarbonate solution
propofol	yellow / orange	no reaction
compound L	~~~~~	~~~~~
compound M	orange / red	fizzing

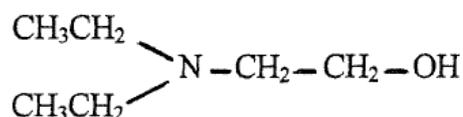
One mark for each correct column [2]

II Gas evolved turns 'lime water' milky [1]

- (f) (i) [1]



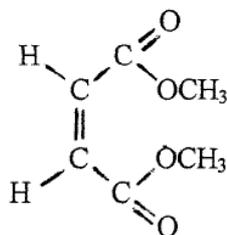
- (ii) [1]



- (g) It would melt at a lower temperature (than 89 °C) / below 89 °C (1)
and over a range of temperature / not a sharp melting temperature (1) [2]

Total [15]

- Q.4 (a) (i) Stereoisomerism is where the compound has the same structural formula but whose atoms / groups take up different positions in space / in three dimensions (1)



[2]

- (ii) The signal at 3.8 δ due to the methoxy protons (1) would disappear and be replaced by a signal at 11.0 δ (1) due to the OH protons (1). These protons would have peak area 2 (rather than peak area 6 for the methoxy protons) (1)
The signal at 6.9 δ would be (largely) unchanged (1) as the C-H bond is not affected by the hydrolysis of the ester. [5]

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter [1]

- (iii) $C_6H_8O_4 \rightarrow 144$
113 is 31 less, could be CH_3O (1)
ion could be $C_5H_5O_3^+$ (1) [2]

- (b) (i) Raw material prices become cheaper / reduce the reaction temperature / use a method where the % yield is increased [1]
- (ii) Use a different (more economic) starting material / find a way of reducing the time taken for fermentation / effect an easier separation method.
Do not accept reference to increased amounts of enzyme / bigger batch. [1]
- (iii) Number of moles of fumaric acid expected = 140 (1)

Actual number of moles of fumaric acid obtained = $\frac{13.0 \times 1000}{116} = 112$ (1)

$$\% \text{ Yield} = \frac{112 \times 100}{140} = 80 \quad (1)$$

Alternatively

180 g / kg of glucose give 2 x 116 g / kg of fumaric acid (1)

\therefore 1 g / kg of glucose gives $\frac{2 \times 116}{180}$ g / kg of fumaric acid

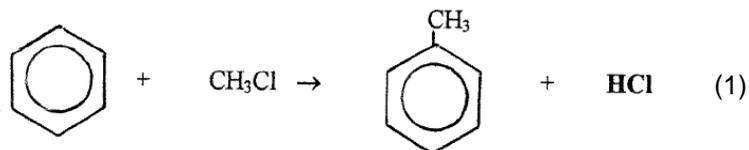
\therefore 12.6 kg of glucose gives $\frac{2 \times 116 \times 12.6}{180}$ kg of fumaric acid = 16.2(4) kg (1)

$$\% \text{ Yield} = \frac{13.0 \times 100}{16.2} = 80 \quad (1)$$

[3]

- (iv) I starting material (1) e.g. ethanol / ethanal OR ethyl ethanoate OR ethanoyl chloride
- reagent (1) $\text{Cr}_2\text{O}_7^{2-} / \text{H}^+$ acid(aq) / base (aq) followed by acidification water
- type of reaction (1) oxidation / redox hydrolysis hydrolysis [3]
- II platinum / nickel [1]
- (c) e.g. Tollens reagent - silver mirror
- OR 2,4 - dinitrophenylhydrazine - yellow/ orange / red precipitate
- OR Fehling's / Benedict's reagent - brown / red precipitate [1]
- Total [20]**

Q.5 (a) (i)



catalyst - aluminium chloride (1) [2]

(ii) Mass of methylbenzene = 27.6 g (1)

$$\text{Moles of methylbenzene} = \frac{27.6}{92.1} = 0.30(0) \quad (1)$$

∴ 0.30 mole of $\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$ should be made
this will have a mass of $0.30 \times 126.6 = 38.0 \text{ g}$ (1)

∴ Mass of flask + product needs to be $120.4 + 38.0 = 158.4 \text{ g}$ (1) [4]

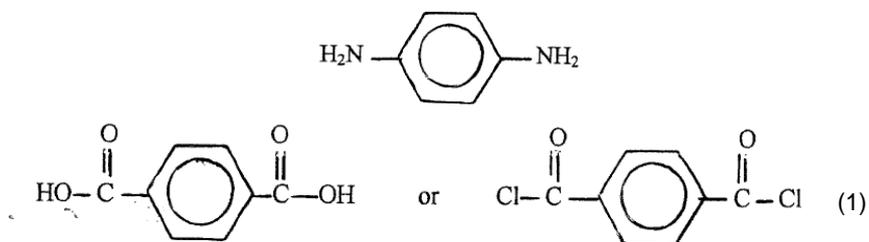
(iii) I potassium cyanide [1]

II lithium tetrahydridoaluminate(III) / lithium aluminium hydride (accept correct formulae) [1]

(b) The nitrogen atom is electron rich / has a lone pair (1) and will act as a proton acceptor / electron pair donor (1) [2]

(c) 2-Phenylethylamine reacts with nitrous acid giving an alcohol (1) and evolving nitrogen gas as bubbles (1)
4-Ethylphenylamine gives a diazonium compound (1) [3]

(d)



[2]

(e) (i) 2-amino-3-hydroxypropanoic acid [1]

(ii) Hydrogen bonding occurs because of the difference in electronegativity between hydrogen and oxygen / nitrogen (in O-H and N-H bonds), (1), leading to polar covalent bonds / δ^+ , δ^- (1)
There are attractive forces between the oxygen or nitrogen of one molecule and the hydrogen atom bonded to an oxygen or nitrogen atom of another molecule (1) [3]

(Marks can be obtained from a suitable diagram)

QWC Information organised clearly and coherently, using specialist vocabulary when appropriate [1]

Total [20]



GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

JANUARY 2012

- (b) (i) It contains an unpaired electron [1]
- (ii) I $\bullet\text{CH}_3 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{Cl}\bullet$ [1]
- II A radical reacts to produce a new radical (that can continue the process) [1]
- (iii) C_7H_{16} [1]
- (iv) (Bond fission where a covalent bond breaks) and each atom receives an electron [1]

Total [13]

- Q.9** (a) Hydrogen bonding occurs between (1) oxygen, nitrogen or fluorine (1) of one molecule and hydrogen, which is bonded to oxygen / nitrogen / fluorine of another molecule (1)
Alkanes do not contain an O-H, N-H or F-H bond and cannot therefore hydrogen bond to water molecules (1) [4]

QWC Candidates should have use 'a selection and form of writing appropriate to purpose and to complexity of subject matter' [1]

- (b) (i) The (purified) petroleum is separated by heating (1) due to the different boiling temperatures of different fractions (1)
OR the mixture is vaporised (1) and then condensed according to boiling temperatures (1) (as at the oil refinery) [2]

- (ii) $\text{CuCl}_2 \quad \text{Cu} +2 \quad \text{CuCl} \quad \text{Cu} +1$ (1)
(reduction occurs when) the oxidation number becomes less positive (1) [2]

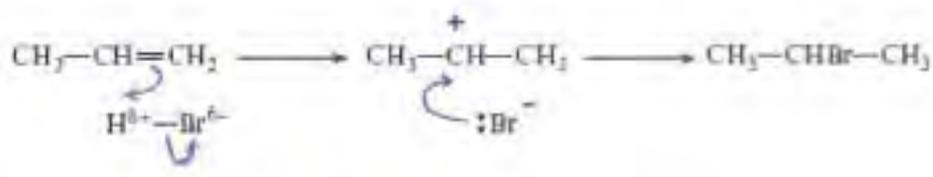
- (c) (i) Same molecular formula but a different structural formula / structure [1]
- (ii) Both of the carbon atoms of the double bond have different atoms / groups bonded to them (1)
There is no free rotation about the double bond (1) [2]

- (iii) M_r of compound **A** is 146.3 / 146 (1)
Cost per mole is $\frac{146.3 \times 48 \times 100}{100 \times 73} = \text{£}96.20$ (1)

(Accept £96.00 per mole if M_r of 146 has been used) [2]

Total [14]

Q.10 (a) (i)



curly arrows (1)
charges (1) [2]

(ii) Nucleophile hydroxide ion / OH⁻ / water (1)

Substitution the replacement of one functional group by another (1) [2]

(iii)



(accept Na⁺ and Br⁻ in place of NaBr) [1]

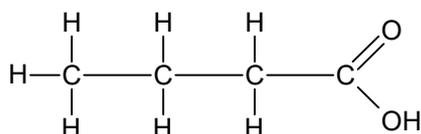
(b) M_r = 88 (1)

$$\text{'M}_r \text{ R} = 88 - (45) = 43 \text{ (1)}$$

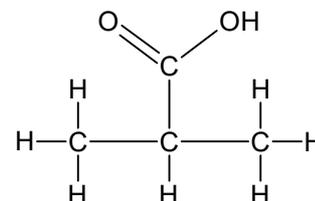
←
COOH

∴ R (an alkyl group) is C₃H₇

thus acid is



or



(1) [3]

(c) In graphite each carbon atom is bonded to three other carbon atoms (1)
(using covalent bonding)

The other (outer) electron for each carbon atom is delocalised (1), throughout the structure and is able to move (1), conducting electricity

In iodine the two iodine atoms are bonded together (using covalent bonding) and there are no free electrons to carry the charge (1)

Mention of covalent bonding for either element (1) [5]

QWC Legibility of text; accuracy of spelling, punctuation and grammar; clarity of meaning (1)

Organisation of information clearly and coherently; use of specialist vocabulary where appropriate (1) [2]

Total [15]

SECTION B TOTAL [70]

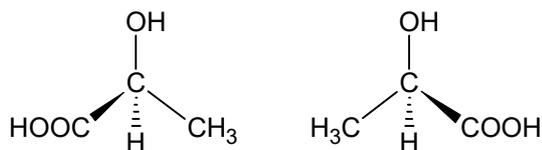
GCE Chemistry – CH4

SECTION A

Q.1	(a)	(i)	A	[1]
		(ii)	D	[1]
		(iii)	C	[1]
		(iv)	C	[1]
	(b)	(i)	Nucleophilic substitution	[1]
		(ii)	The C–Cl bond in chlorobenzene is stronger than in 1-chlorobutane (1) due to delocalization of electron density from the ring with the bond (1)	
			OR	
			Delocalised electrons in chlorobenzene (1) repel lone pair of electrons on nucleophile / ammonia (1)	[2]
		(iii)	$C_4H_9NH_2 + CH_3COCl \longrightarrow C_4H_9NHCOCH_3 + HCl$	[1]
		(iv)	I Tin and concentrated hydrochloric acid (1) Add sodium hydroxide (after cooling) (1) Steam distillation to separate the product (1)	[3]
			II $C_6H_5NN^+Cl^-$	[1]
			III Azo dye / azo compound	[1]
Total				[13]

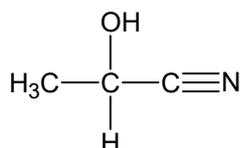
Q.2 (a) (i) A compound that can rotate the plane of polarised light. [1]

(ii)



[1]

(iii)



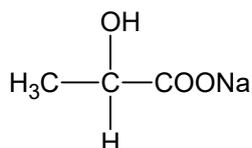
[1]

(iv) Reflux / heat with $\text{H}_2\text{O}/\text{H}^+$ [1]

(v) It contains an equal amount of the two enantiomers / it is a racemic mixture (1)

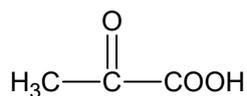
The rotating effect of one form exactly cancels out the effect of the other (1) [2]

(b) (i)



[1]

(ii)



[1]

(c) (i) 2-aminopropanoic acid [1]

(ii) Nitrous acid / nitric(III) acid / HNO_2 [1]

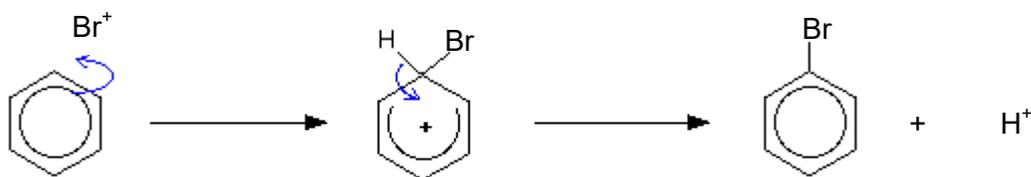
(iii) It exists as a zwitterion (1)

strong electrostatic attractions / ionic bonds between different zwitterions (1) [2]

Total [12]

Q.3 (a) (i) Electrophilic substitution [1]

(ii)



Formation of Br^+ (1), curly arrows (1), intermediate (1) [3]

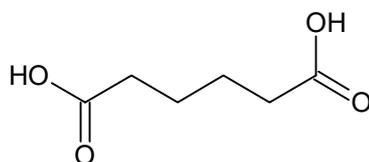
(b) (i) The extra stability in the benzene molecule due to electron delocalisation / the difference in energy between the experimental ΔH^\ominus reaction for benzene and the ΔH^\ominus reaction according to the Kekulé structure [1]

(ii) If benzene had 3 double bonds enthalpy change would be $3 \times -120 = -360 \text{ kJ mol}^{-1}$ (1)

Delocalisation energy is difference between -360 and $-208 = 152 \text{ kJ mol}^{-1}$ (1) [2]

(c) Benzene is carcinogenic / toxic [1]

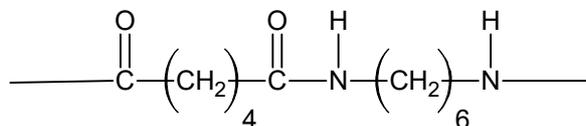
(d) (i) [1]



(ii) Reduction [1]

(iii) 1, 6-diaminohexane [1]

(iv) [1]



(v) Polyamide [1]

(vi) 226 tonnes nylon require 156 tonnes benzene (1)

800 tonnes nylon require $800 \times \frac{156}{226} = 552$ tonnes (1) [2]

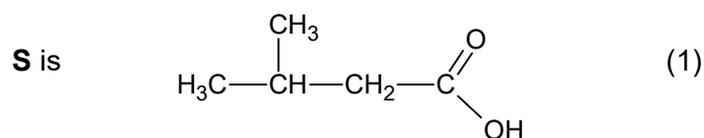
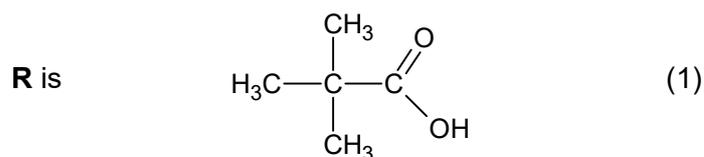
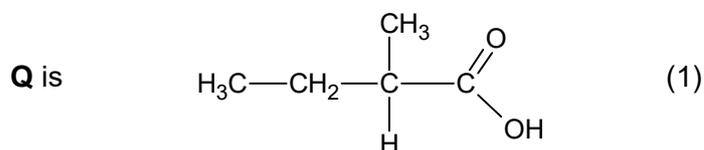
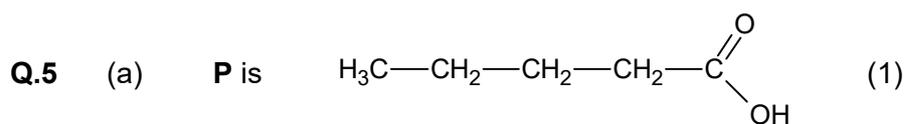
Total [15]

SECTION A TOTAL [40]

SECTION B

- Q.4** (a) (i) Moles NaOH = 5.675×10^{-3} (1)
 $M_r \text{ O} = \frac{0.50}{0.005675} = 88.1$ (1) [2]
- (ii) **K** contains C=O due to 2, 4-dinitrophenylhydrazine reaction (1)
 Contains CH₃CO due to positive iodoform test (1)
 From M_r **K** must be CH₃COCH₃ (1)
O contains COOH due to neutralisation / decarboxylation reaction (1)
 From M_r **O** must be CH₃CH₂CH₂COOH / (CH₃)₂CHCOOH (1) [5]
- (iii) **L** is CH₃CH(OH)CH₃ (1)
M is C₃H₆ (1)
N is C₃H₈ (1) [3]
- (iv) Concentrated H₂SO₄ / Al₂O₃ / concentrated H₃PO₄ [1]
- (b) (i) To form the acid from the salt / to precipitate the acid / the salt is water soluble [1]
- (ii) The acid is soluble in hot water but insoluble in cold water [1]
- (iii) Moles = $3.2/40 = 0.08$ (1)
 Concentration = $0.08/0.04 = 2 \text{ mol dm}^{-3}$ (1) [2]
- (iv) Mass = $2.90 \times 1.06 = 3.074 \text{ g}$ (1)
 Moles = $3.074/150.1 = 0.0205$ (1) [2]
- (v) Maximum mass = $0.0205 \times 122 = 2.50 \text{ g}$ (1)
 % yield = $1.45/2.50 = 58.0\%$ (1) [2]
- (vi) Hydrolysis not complete / equilibrium forms / C₆H₅COOH slightly soluble in water / two stages so some loss at both / mass lost during recrystallisation [1]

Total [20]



[4]

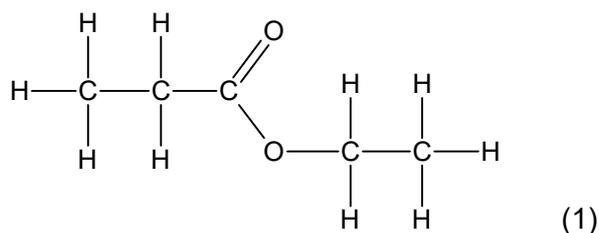
(b) (i) **T** neutral and sweet-smelling therefore an ester (1)

Infrared spectrum at 1750 cm^{-1} shows C=O and at 3000 cm^{-1} shows O-H therefore **X** is an acid (1)

Y is an alcohol, formed from ethanal must be ethanol (1)

5 carbons in ester therefore **X** must be propanoic acid (1)

Structure of **T** is



(Maximum 4 marks)

[4]

QWC Legibility of text; accuracy of spelling, punctuation and grammar, clarity of meaning (1)

Selection of a form and style of writing appropriate to purpose and to complexity of subject matter (1) [2]

(ii) I Reagent to form **Y** is NaBH_4 / LiAlH_4 [1]

II Sulfuric acid acts as a catalyst / removes water so pushes equilibrium to right [1]

(c)	$\text{CH}_3(\text{CH}_2)$	0.1 to 2.0 ppm triplet (1)	
	$(\text{CH}_3)\text{CH}_2\text{O}$	3.5 to 4.0 ppm quadruplet (1)	
	CH_2CO	2.5 to 3.0 ppm singlet (1)	
	CH_3CO	2.0 to 2.5 ppm singlet (1)	[4]

(d) Isomer **P** (1)

Only P can form hydrogen bonds between molecules (1)

Hydrogen bonds are the strongest intermolecular bonds / need more energy to break hydrogen bonds (1) [3]

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

Total [20]

SECTION B TOTAL [40]



GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

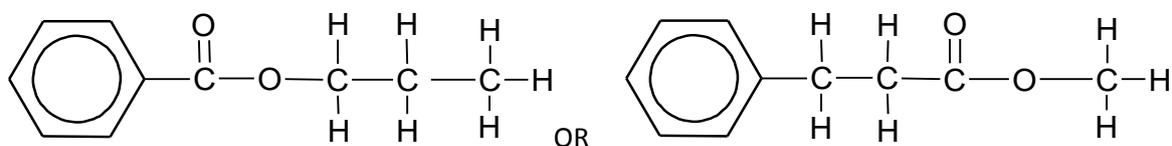
SUMMER 2012

CH4

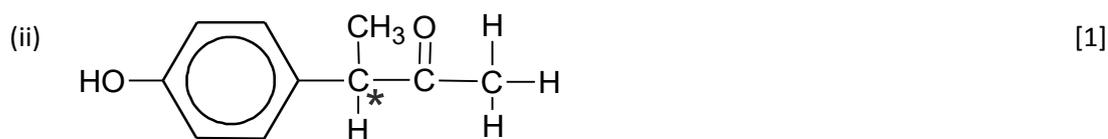
Question 1

(a) Any valid ester structure with formula $C_{10}H_{12}O_2$ [1]

Examples:



(b) (i) Compound X [1]



(iii) Rotate the plane of polarised light in opposite directions [1]

(c)

<i>Reagent(s)</i>	<i>Observation if the test is positive</i>	<i>Compound(s) that would give a positive result</i>
$I_2 / NaOH$ (aq)	Yellow solid	X
Na_2CO_3 (aq)	Bubbles of colourless gas / effervescence	W
$FeCl_3$ (aq)	Dark purple/blue/green - do not accept 'precipitate'	X, Z

(1 mark for each box) [6]

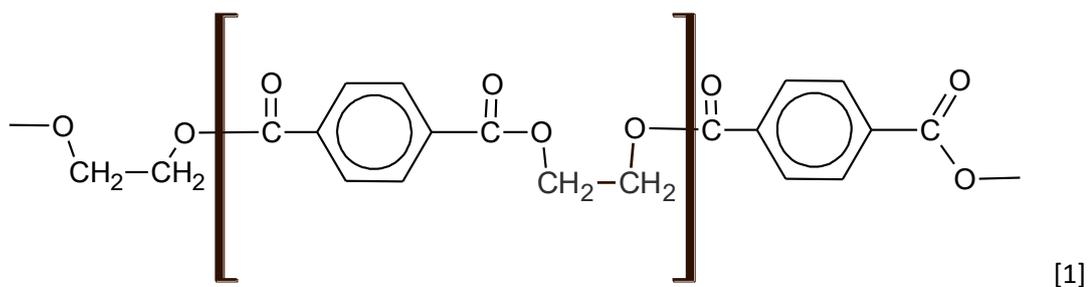
(d) (i) Heat / Alkaline / Potassium manganate(VII) / then acidify
(1 mark for Potassium manganate + 1 other point; 2 marks for all) [2]

(ii) I. Addition polymer – One large molecule formed only / Condensation polymer – one large molecule with small molecules (e.g. water) lost. (1)

Addition polymer – one starting material / Condensation – two starting materials

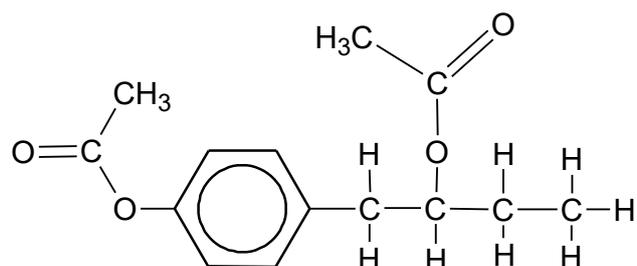
OR Addition polymer – one functional group in each molecule/ Condensation polymer – two functional groups in each molecule (1) [2]

II.



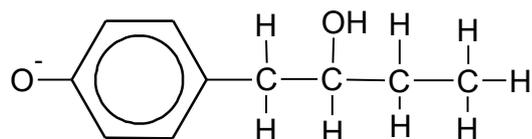
(e) (i) NaBH_4 / LiAlH_4 or name(1) Reduction (1) [2]
- ignore conditions unless LiAlH_4 in water - do not accept 'redox'

(ii)



Accept structures with only one $-\text{OH}$ group reacted. [1]

(iii) [1]



[19 marks]

Question 2

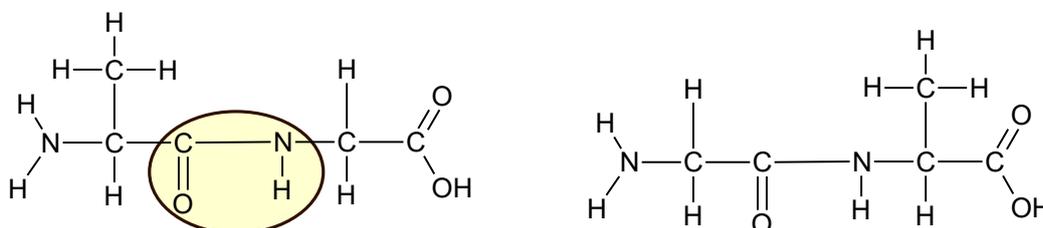
- (a) (i) Alanine forms a zwitterion (1)

Forces between alanine molecules are ionic bonding (1)

Ionic bonding much stronger than hydrogen bonding / van der Waals (1)

Max 2 marks [2]

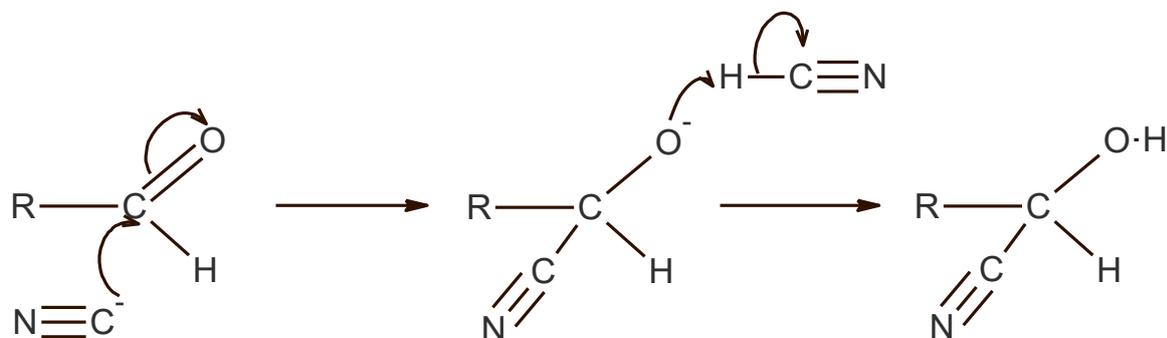
- (ii) 1 mark for each correct structure [2]



- (iii) 1 mark for correct identification of peptide link [1]

- (b) Enzymes / Structural proteins / Hormones or specific example [1]

- (c) 1 mark for arrows in first stage; 1 mark for correct intermediate; 1 mark for arrow giving gain of proton in second stage (from HCN or from H
- ⁺
-).



[3]

- (d) Soda lime [1]

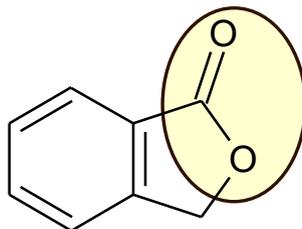
[1]

[10 marks]

Question 3

(a) (i)

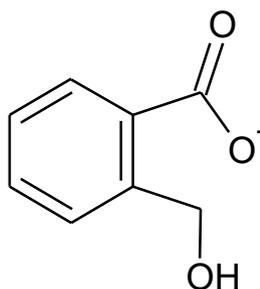
[1]



Phthalide

(ii)

[1]



(b) Distillation / Chromatography

[1]

(c) Hydrogenation of 3-butyl phthalide removes a benzene ring (1)

Benzene ring is more stable than alkene/ Reference to delocalisation energy (1) [2]

(d) 62.1%

[1]

(e) (i) Greater variety of different phthalides that can be produced

[1]

(ii) Higher atom economy / less waste / carbon monoxide is toxic

[1]

- do not accept references to yield

(f) Silver nitrate and ammonia / Tollen's reagent (1); Q = Silver mirror (1); R = No reaction (1)

OR 2,4,-DNP (1); Orange precipitate with Q (1); No reaction with R (1)

OR Fehling's solution (1); Orange solid with Q (1); No reaction with R (1)

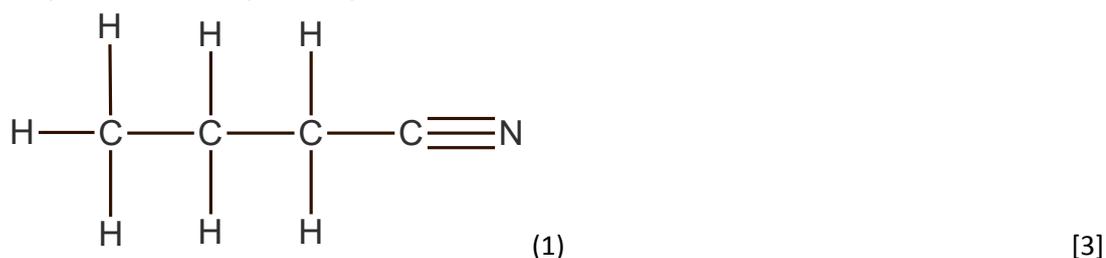
[3]

[11 marks]

Question 4

- (a) (i) Nucleophilic substitution / Hydrolysis [1]
- (ii) Dissolved in alcohol (1) Propene or unambiguous structure (1) [2]
- (iii) Potassium manganate(VII) / Potassium dichromate(VI) - must be **name** (1) [1]
Oxidation (1) [2]
- (iv) (Add Potassium dichromate(VI)) and distil off the propanal from the reaction mixture [1]

- (b) (i) Step 1: Potassium cyanide in ethanol / Heat (1)
Step 2: Heat with aqueous hydrochloric acid (or other acid) (1)



- (ii) Two points from different bullet points – 1 mark each.
- Atom economy / Amount of waste / Whether waste material was recyclable / Whether waste was toxic.
 - Amount of energy required / temperature required / pressure required / conditions used
 - Rate of production / time
 - Availability of catalyst
 - Cost of reactants / Availability of reactants / toxicity of reactants.
 - Two step processes usually have lower yields than one step processes / percentage yield [2]
 - Purification method / separation

- (c) (i) Butanoic acid is $\text{C}_4\text{H}_8\text{O}_2$ so $M_r = 88$ (1)
Percentage carbon = $48/88 \times 100 = 54.5\%$; percentage hydrogen = $8/88 = 9.1\%$;
Percentage oxygen = $32/88 = 36.4\%$ (At least two of these for 1)
OR empirical formula for butanoic acid = $\text{C}_2\text{H}_4\text{O}$ (1) and
calculate empirical formula from percentage masses = $\text{C}_2\text{H}_4\text{O}$ (1) [2]

(ii) Structure 1 mark + 4 marks for explanations.

- Product is ethyl ethanoate. (1)
- Two points from the following required for each mark– MAX 4 marks
 - Sweet-smelling = ester
 - Peak at 1.0ppm implies – CH₃
 - Peak area 3 = CH₃
 - Peak area 2 = CH₂
 - Triplet shows CH₃ is next to a CH₂ group.
 - Singlet shows CH₃ no hydrogen atoms bonded to adjacent carbon.
 - Peak at 2.1 ppm suggests this is next to C=O.
 - Quartet shows CH₂ is adjacent to a CH₃ group.
 - Peak at 4.0 ppm shows it is –O-CH₂-
 - IR Peak at 1752 cm⁻¹ = C=O
 - IR Peak at 2981 cm⁻¹ = C-H or O-H
 - Cannot be –OH as we know there is no –OH in NMR spectrum

[5]

QWC: selection of a form and style of writing appropriate to purpose and to complexity of subject matter. (1)

QWC: organisation of information clearly and coherently; use of specialist vocabulary where appropriate. (1)

[2]

[20 marks]

Question 5

(a) (i) (Concentrated) nitric acid / (concentrated) sulfuric acid / Temperature of 40-80°C

(Any 2 = 1 mark; All 3 = 2 marks)

Electrophilic substitution (1) [3]

(ii) I. Peak area is proportional to amount of substance (1)

Percentage = $(30 / 38) \times 100 = 79\%$ (1)

(Can obtain both marks from correct percentage) [2]

II. 45 = COOH^+ , 46 = NO_2^+ , 122 = $\text{C}_6\text{H}_4\text{NO}_2^+$ and 167 = $\text{C}_7\text{H}_5\text{NO}_4^+$.

(Any 2 = 1 mark; All 4 = 2 marks) [2]

(iii) I. Lower melting point / melts over a range [1]

II. 1 mark for each point.

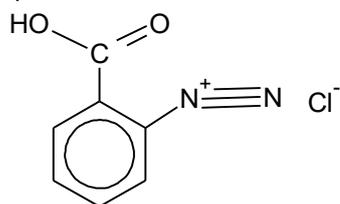
- Dissolve in the minimum volume
- Of hot water
- Filter hot
- Allow to cool
- Filter
- Dry residue under suction / in oven below 142°C

Max 4 marks [4]

QWC: legibility of text, accuracy of spelling, punctuation and grammar, clarity of meaning. [1]

(b) (i) Tin and concentrated hydrochloric acid [1]

(ii) Below 10°C (1)



(1) [2]

(iii) N=N double bond is chromophore (1)

Compound absorbs blue /green / complementary colours to red / all colours but red (1)

Remaining frequencies are transmitted, giving the red colour seen. (1)

Any 2 out of 3 [2]

(c) Nitrogen has a lone pair (1) which can accept a proton (1) [2]

[20 marks]



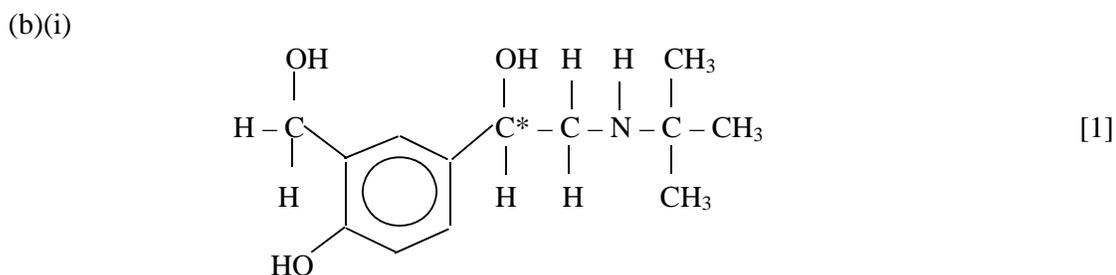
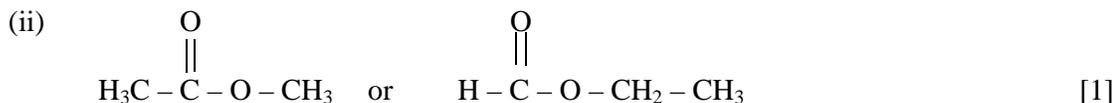
GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

JANUARY 2013

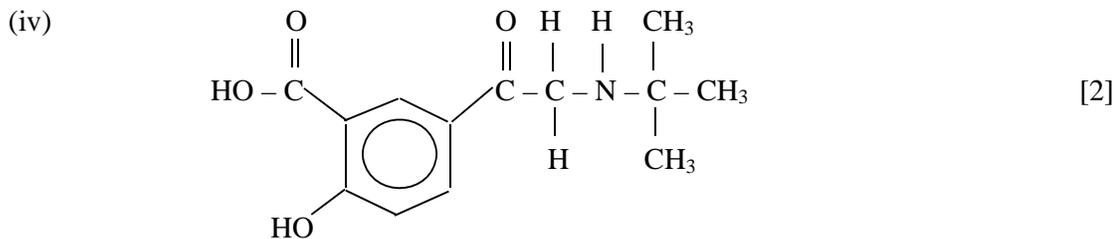
GCE CHEMISTRY - CH4
JANUARY 2013 MARK SCHEME

Section A



(ii) The isomers rotate the plane of polarised light in opposite directions [1]

(iii) Side effects from other optical isomer / lower dose needed / improved pharmacological activity / only one isomer has correct orientation to bind with biological molecule [1]



(1 mark for acid (accept aldehyde), 1 mark for ketone)

(c)(i) Ethylamine, ethanol, phenol, ethanoic acid [1]

(ii) Ethylamine is basic because it accepts a proton readily (1) due to the lone pair of electrons on the nitrogen. (1)
 Phenol is acidic because it loses a proton / the anion formed is stabilised (1) by delocalisation of the negative charge over the benzene ring. (1)
 (Accept description e.g. in phenoxide ion lone pairs of electrons on oxygen become delocalised with electrons in benzene ring.) [4]

Total [14]

2. (a)

	Butan-2-ol	Ethanal	Ethanol	Propanone
2,4-DNP	No reaction	Yellow-orange precipitate	No reaction	Yellow-orange precipitate
Tollens' reagent	No reaction	Silver mirror	No reaction	No reaction
I ₂ /NaOH	Yellow precipitate	Yellow precipitate	Yellow precipitate	Yellow precipitate

(1 mark for each column) [4]

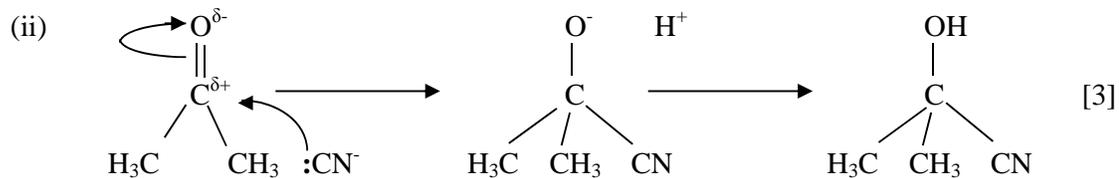
(b)(i) Electrophilic addition [1]

(ii) Carbonium ion / carbocation / electrophile [1]

(iii) Bromination / HBr addition / hydrogenation [1]

(iv) Secondary carbocation more stable than primary carbocation [1]

(c)(i) Nucleophilic addition [1]



1 mark electron movement
1 mark charges

1 mark intermediate
and electron movement

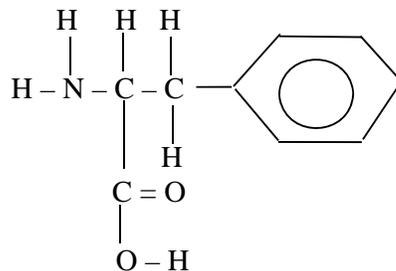
(Accept $\text{CN}^{\delta-} - \text{H}^{\delta+}$ for CN^-)

Total [12]

3. (a) Intermolecular bond formed (1) when hydrogen attached to a highly electronegative atom (1) is bonded to an electronegative atom attached to hydrogen (in another molecule) (1) forming a very strong dipole – dipole attraction (1) [3]
(maximum 3 marks)

QWC Legibility of text; accuracy of spelling, punctuation and grammar, clarity of meaning [1]

(b)

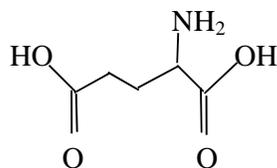


[1]

- (c) Behaves as / can react with an acid or a base (1)

-COOH is an acidic group / donates proton, -NH₂ is a basic group / accepts proton (1)
[2]

(d)



[1]

- (e) Moles MSG = $1/169.08 = 5.91 \times 10^{-3}$ (1)

Concentration = $5.91 \times 10^{-3} / 0.1 = 5.91 \times 10^{-2}$ (1) [2]

- (f) (Neutral) FeCl₃ / Br₂ (1)

Purple colour / white precipitate (1) [2]

- (g) 2,4-Dinitrophenylhydrazine / acidified sodium dichromate (1)

Yellow-orange precipitate / orange to green colour change (1) [2]

Total [14]

Total Section A [40]

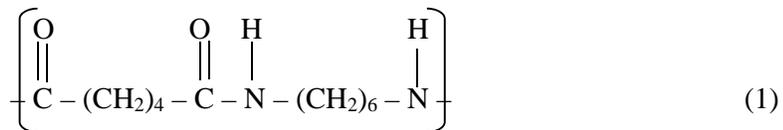
Section B

4. (a) For synthetic polymer:

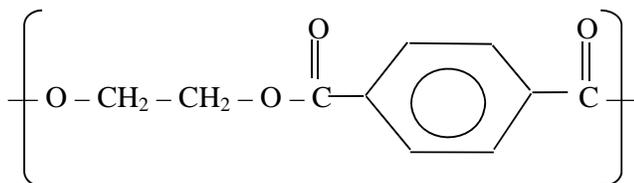
Monomers: 1,6-Diaminohexane / ethane-1, 2-diol (1)

Hexanedioic acid / benzene-1,4-dioic acid (1)

Structure:



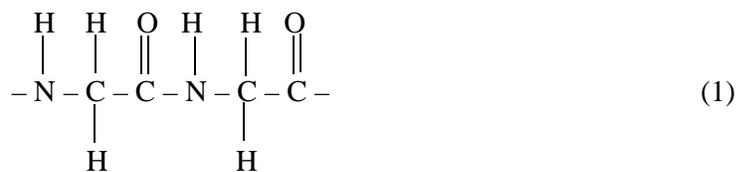
or



For natural polymer:

Monomers: aminoethanoic acid / 2-aminopropanoic acid (1)

Structure: e.g.



[5]

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter

[1]



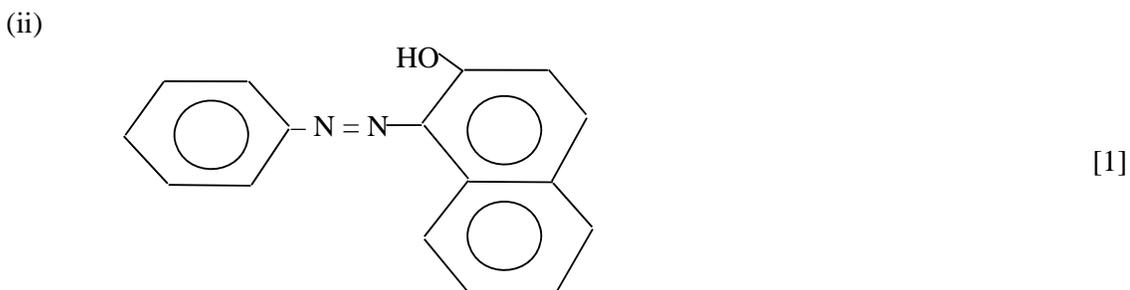
(ii) 1,4-dichlorobenzene [1]

(iii) Chlorine (in the absence of ultraviolet light) (1)
 AlCl_3 / FeCl_3 (as a halogen carrier) (1) [2]

(iv) Heat with NaOH (aq) (1)
 add HNO_3 (aq) followed by AgNO_3 (aq) (1)
F gives white precipitate, **G** does not (1)
 In **F**, the C–Cl bond is polarised / contains $\text{C}^{\delta+}$ or undergoes nucleophilic substitution (1)
 In **G** due to delocalisation of the π electron cloud of the ring with the p-orbital electrons of the chlorine (1)
 the C–Cl bond is too strong to break/ does not undergo nucleophilic substitution (1)
 [6]

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

(c)(i) To prevent decomposition of benzenediazonium chloride / HNO_2 [1]



(iii) A chromophore is the group of atoms responsible for the colour of the compound (by causing absorption in the visible region of the spectrum) [1]

Total [20]

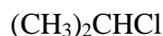
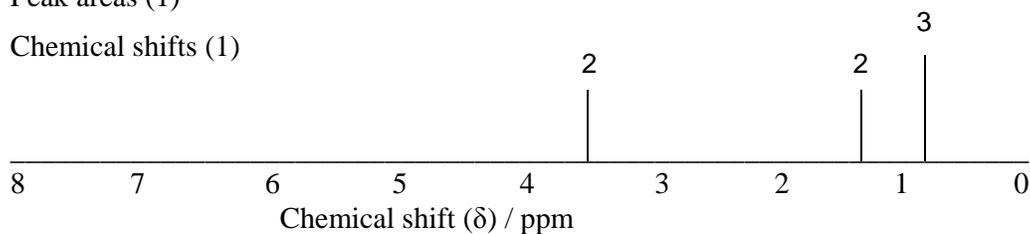
5. (a)(i) Moles HCl = 5.4×10^{-3} (1)
 $M_r \mathbf{B} = \frac{0.395}{0.0054} = 73.1$ (1) [2]

- (ii) **B** is basic therefore must be amine (1)
C reacts with Na_2CO_3 therefore must be an acid (1)
D is oxidised to **C** therefore must be an alcohol (1)
A hydrolyses to acid but does not contain oxygen therefore must be nitrile (1)
B is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$ (1)
C is $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ (1)
D is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ (1)
A is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$ (1) [8]
 (4 marks structures – if 3 carbons in chains penalise only once
 4 marks reasons – accept alternative reasons)



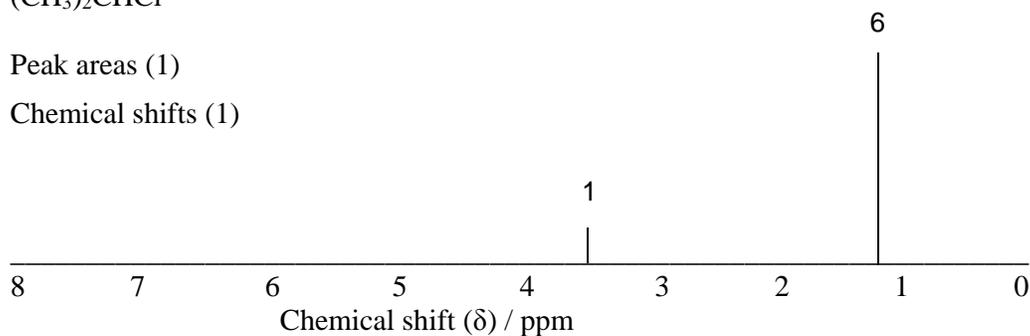
Peak areas (1)

Chemical shifts (1)



Peak areas (1)

Chemical shifts (1)



- (c)(i) 2 steps instead of 3 / CH_3COCH_3 can be sold / reagents are cheaper / gives a higher yield / easier to extract phenol / phenol formed more quickly / fewer reactants [2]
 (Accept any 2)

- (ii) Lower temperature required / catalyst costs less / catalyst less likely to break up / catalyst less toxic or safer [1]

(d) Moles phenol = $58.75/94.06 = 0.625$ (1)
 Maximum mass aspirin = $0.625 \times 180.08 = 112.55 \text{ g}$ (1)
 65% yield, therefore mass aspirin = 73.16 g (1) [3]

Total [20]

Total Section B [40]



GCE MARKING SCHEME

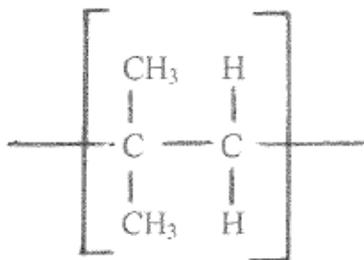
**CHEMISTRY
AS/Advanced**

SUMMER 2013

GCE CHEMISTRY – CH4

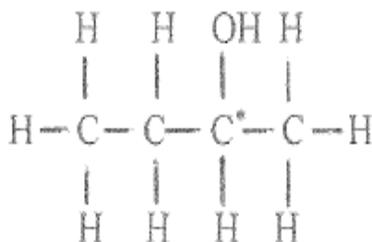
SUMMER 2013 MARK SCHEME

- Q.1 (a) (i) (2-)Methylpropan-2-ol [1]
- (ii) 30.1 / 30 [1]
- (iii) (Concentrated) sulfuric acid / phosphoric acid / aluminium oxide / pumice [1]
- (iv)



(with or without n) [1]

(v)



(1) for structure, (1) for asterisk [2]

- (vi) I acidified potassium dichromate / H^+ , $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ [1]
- II ethanal has a $\text{C}=\text{O}$ bond at $1650\text{-}1750\text{ cm}^{-1}$
(metaldehyde does not have this bond) (1)
- metaldehyde has a $\text{C}-\text{O}$ bond at $1000\text{-}1300\text{ cm}^{-1}$
(ethanal does not have this bond) (1) [2]

- (b) (i) **Reagent** 2,4-dinitrophenylhydrazine / 2,4-DNP OR iodine / NaOH or KI / NaOCl (1)
Observation yellow / orange / red precipitate OR yellow precipitate (1) [2]
- (ii) **Reagent** ethanol / sulfuric acid OR NaHCO_3 OR Ag^+/NH_3 / Tollens' (1)
Observation sweet smelling liquid OR effervescence OR silver mirror (1) [2]

Total [13]

- Q.2** (a) React with iron(III) chloride solution
Purple solution with phenol, no reaction with methyl propenoate

OR

React with aqueous bromine / bromine water

White precipitate with phenol (and bromine decolourised), bromine decolourised with methyl propenoate

(1) for reagent and (1) for observation with compound [2]

- (b) (i) It absorbs all colours except yellow / absorbs the blue end of the spectrum and reflects yellow – do not accept 'emits' [1]

- (ii) Tin / iron and concentrated hydrochloric acid [1]

- (c) (i) Moles of 2,4-dinitrophenol = $7.36/184 = 0.040$ (1)
Moles of 2,4-dinitrophenyl ethanoate = $7.91/226 = 0.035$ (1)
Percentage yield = $0.035 \times 100 / 0.040 = 87.5 / 88 \%$ (1) [3]

- (ii) R_f value is given by $\frac{\text{distance travelled by the 2,4-dinitrophenol}}{\text{distance travelled by the solvent front}}$ (1)
 $= \frac{2.8}{5.0} = 0.56$ (1) [2]

- (d) (i) Nickel / platinum [1]

- (ii) The –OH groups are able to hydrogen bond with water (1)
but these are a very small part of the 'urushiol' molecule (1) [2]

Total [12]

- Q.3** (a) (i) 48.5 / 49 % [1]
- (ii) Find a use for the calcium sulfate [1]
- (b) Total volume of aqueous sodium hydroxide needed = $\frac{26.40 \times 250}{25.00} = 264.0 \text{ cm}^3$ (1)
- from the graph this is equivalent to 0.011 mole of the acid (1)
- $\therefore M_r$ of the acid = $\frac{\text{mass}}{\text{no. of moles}} = \frac{2.31}{0.011} = 210$ (1)
- $$\begin{array}{c} \text{C}_6\text{H}_8\text{O}_7 \cdot n \text{H}_2\text{O} = 210 \\ \uparrow \\ 192 \end{array} \therefore n = 18 \quad (1)$$
- since M_r of water is 18 $n = 1$ (1) [5]
- (c) The two 'ends' of the double bond have different groups bonded to the carbon atoms (of the double bond) / they have different structural formulae, so cannot be stereo / geometric isomers [1]
- (d) eg sodium ethanoate / ethanoic acid (1) methane (1) [2]
- (e) $\text{C}_5\text{H}_6\text{O}_5 \rightarrow \text{CH}_3\text{COCH}_3 + 2\text{CO}_2$ [1]
- (f)
- $$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C} & - \text{C} & - \text{O} - \text{H} \\ & / & \diagdown \\ \text{H}' & & \text{H} \\ & | & \\ \text{H} - \text{C} & - \text{O} - \text{H} \\ & | & \\ \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C} & - \text{C} & - \text{O} - \text{H} \\ & / & \diagdown \\ \text{H} & & \text{H} \end{array}$$
- [1]
- (g) (Fractional) distillation / (preparative) gas chromatography / HPLC [1]
- (h) (i) eg An optically active isomer that will rotate the plane of polarised light / an isomer with a chiral centre [1]
- (ii) An equimolar mixture of both enantiomers (that has no apparent effect on the plane of polarised light) [1]

Total [15]

- Q.4** (a) Benzene is a compound whose molecules contain six carbon atoms bonded in a (hexagonal) ring (1)
 All the carbon to carbon bond lengths are equal / intermediate (1)
 Each carbon atom is bonded to two other carbon atoms and a hydrogen atom (1)
 by σ -bonds (1)
 All the C – C – C angles are the same / 120° (1)
 The remaining p electron of each carbon atom / overlap of p orbitals forms a delocalised cloud of electrons / π -system (1) above and below the plane (1)
 Credit can be gained from labelled diagram
 [Candidates can gain a maximum of (4) for this part]

This delocalisation increases the **stability** (1) of the molecule and this stability is maintained by benzene undergoing substitution reactions in preference to addition reactions (that would destroy the delocalised system)

The π -cloud is **electron rich** and will be attracted to electron deficient electrophiles (1)
 [Candidates can gain (2) for this part]

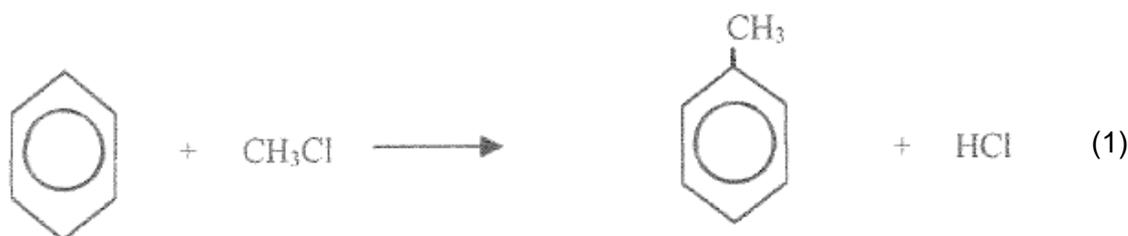
[6]

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter (1)

Legibility of text; accuracy of spelling, punctuation and grammar; clarity of meaning. (1)

QWC [2]

(b)



catalyst eg AlCl_3 (anhydrous) (1)

[2]

- (c) (i) (There are two environments for the protons), the 3 aromatic protons at $\sim 6.8 \delta$ and the 9 methyl / aliphatic protons at $\sim 2.3 \delta$ (1)
 These give a peak area of 3:9, ie. 1:3 (1)
 These environments are separate / discrete (1) therefore no splitting pattern

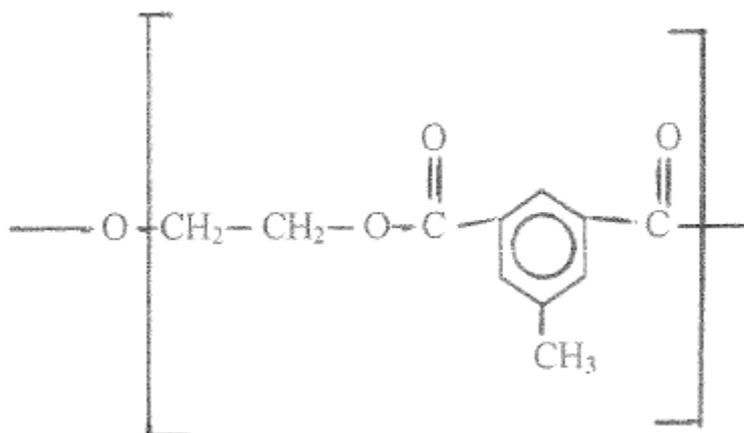
[3]

- (ii) Dissolve in the minimum volume (1)
 Of hot water (1)
 (Filter hot) (1)
 Cool (1)
 Filter (1)
 Dry (1)

(up to 4 max but candidates must give the first two points in order to gain full credit)

[4]

(iii)



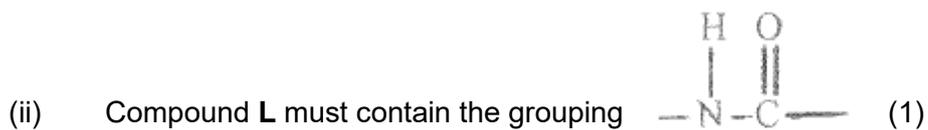
[1]

- (iv) Reagent **S** is alkaline potassium manganate(VII) (1)
 Reagent **T** is eg hydrochloric acid (1)

[2]

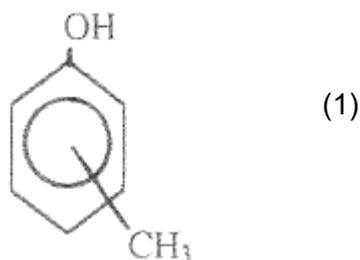
Total [20]

- Q.5** (a) (i) The **nitrogen atom** has a **lone pair** of electrons making it an electron pair donor / proton acceptor [1]



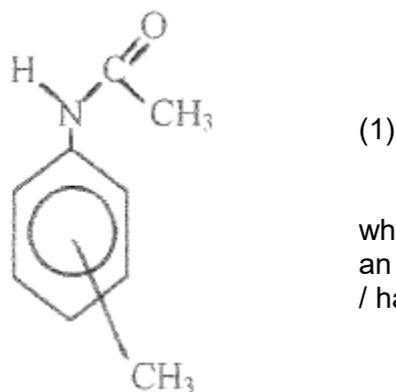
The nitrogen atom must be bonded directly to the ring as a (primary) aromatic amine is formed on hydrolysis (1)

As the hydrolysis compound is a phenol (and has an OH group directly bonded to the ring) a methyl group must also be bonded directly to the ring, as the molecular formula is $\text{C}_7\text{H}_8\text{O}$ / the compound has the structure



The compound is likely to be an amide, as these are hydrolysed by bases to amines (1)

A suggested formula is



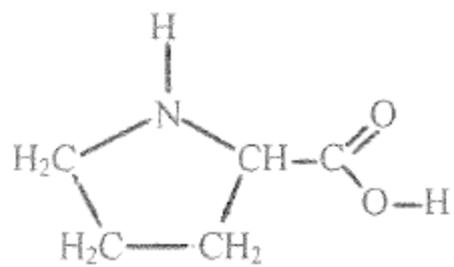
which is $\text{C}_9\text{H}_{11}\text{NO}$,
an isomer of cathinone
/ has M_r of 149(1)

[6]

QWC Information organised clearly and coherently, using specialist vocabulary where appropriate

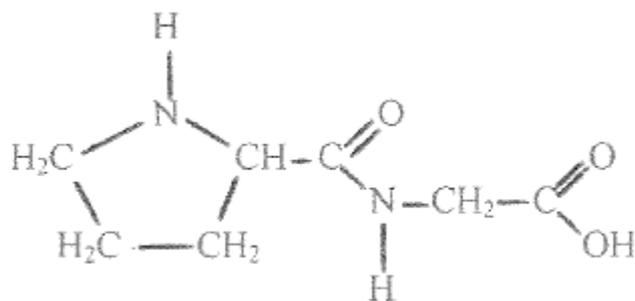
QWC [1]

(b) (i)

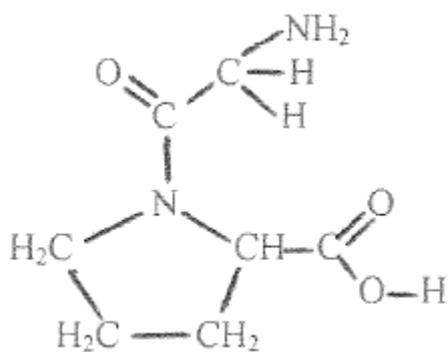


[1]

(ii)

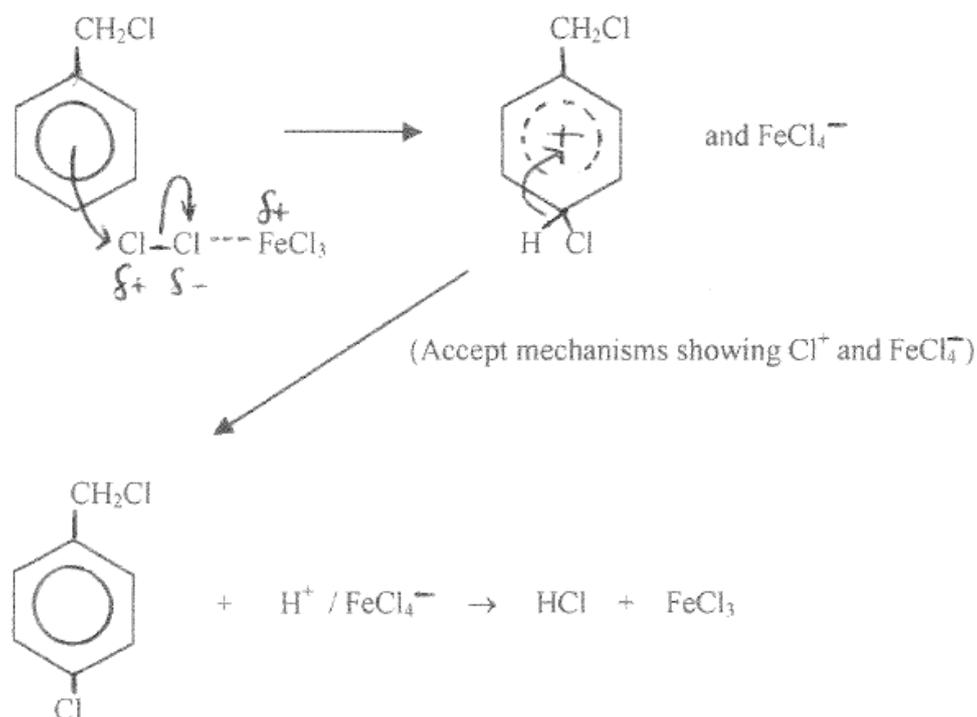


OR



[1]

(c) (i)



Correct catalyst (1)

Correct curly arrows and polarisation / formation of Cl^+ (1)Wheland intermediate (1) Production of HCl and regeneration of FeCl_3 (1)

[4]

(ii) Volume of sodium hydroxide solution needed (1)

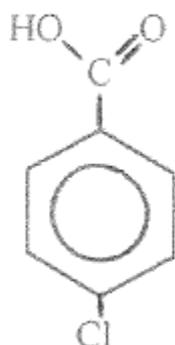
How long to reflux (1)

[2]

(iii) The aromatic C – Cl bond is stronger than the aliphatic C – Cl bond (1)

This is because a p-electron(s) of the chlorine atom in the aromatic compound becomes part of / incorporated into the delocalised π system of the ring (1) [2]

(iv)



(1)

chlorine has two isotopes 35/37
in a 3:1 ratio (1)

[2]

Total [20]



GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

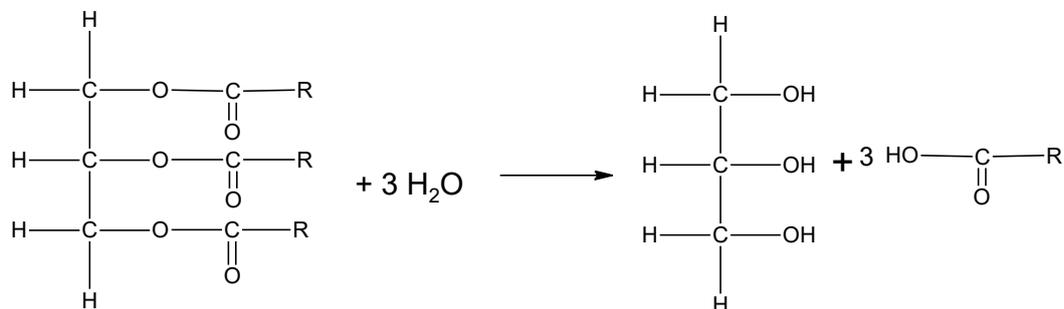
JANUARY 2014

CH4

Section A

Q.1 (a) Reagent(s): (aqueous) sodium hydroxide followed by acid (1)

Condition(s): Heat (to reflux) (1)



[IF NO ACID LISTED IN REAGENT, THEN EQUATION SHOULD CONTAIN SODIUM SALTS] (1) [3]

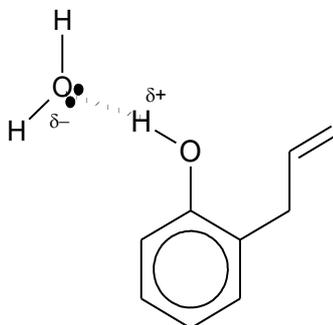
- (b) (i) Reagent(s): (aqueous) bromine (1) [2]
 Observation(s): Changes from orange to colourless (1) [2]
- (ii) Nickel / Platinum / Palladium [1]
- (iii) Moles of hydrogen gas = $1.15 \div 24.0 = 4.79 \times 10^{-2}$ mol (1)
 Moles of stearic acid produced = $4.79 \times 10^{-2} \div 2 = 2.40 \times 10^{-2}$ mol (1)
 Mass of stearic acid = $2.40 \times 10^{-2} \times 284 = 6.80$ g (1) [3]
- (c) (i) **C** $69.7 \div 12 = 5.808$ **H** $11.7 \div 1.01 = 11.584$ **O** $18.6 \div 16 = 1.163$ (1)
 Empirical formula = $\text{C}_5\text{H}_{10}\text{O}$ (1) [2]
- (ii) $\text{C}_{10}\text{H}_{20}\text{O}_2$ [1]
- (d) e.g. biodiesel is renewable/won't run out / carbon neutral
 do not accept 'produces less carbon dioxide' [1]

Total [13]

- Q.2 (a) Chromophore [1]
- (b) (i) Melting temperature **lower** than literature value / melting occurs over a temperature range [1]
- (ii) Identify percentage or amount of impurities (1)
Identify the number of compounds present or number of impurities (1) [2]
- (c) (i) Acidified potassium dichromate (1)
Heat and distil (1) do not accept 'reflux' [2]
- (ii) M_r of phenylmethanol = 108.08 M_r of benzenecarbaldehyde = 106.06 (1)
100% conversion would be $10.0 \div 108.08 \times 106.06 = 9.815\text{g}$ (1)
86% yield = $9.815 \times 86 \div 100 = 8.44\text{g}$ (1) [3]
- (iii) Two resonances in the range 5.8-7.0 ppm (1)
These are doublets (1)
One **singlet** at around 11.0 ppm (1)
All resonances have the same area (1) [4]

Total [13]

- Q.3 (a) Isomers [1]
- (b) (i) Peak at $2500-3550\text{ cm}^{-1}$ present in product but not reactant [1]
- (ii) Add FeCl_3 (1)
Forms a purple solution (1) do not accept 'precipitate' [2]
- (iii) 1 mark for correct location of hydrogen bond; 1 mark for dipole OR lone pair e.g.



[2]

- (c) Aromatic Claisen product is more acidic / better proton donor than product of 1,2-Wittig rearrangement (1)

The 1,2-Wittig rearrangement product is an alcohol, so the charge on the **anion** formed is localised / the **anion** is unstable (1)

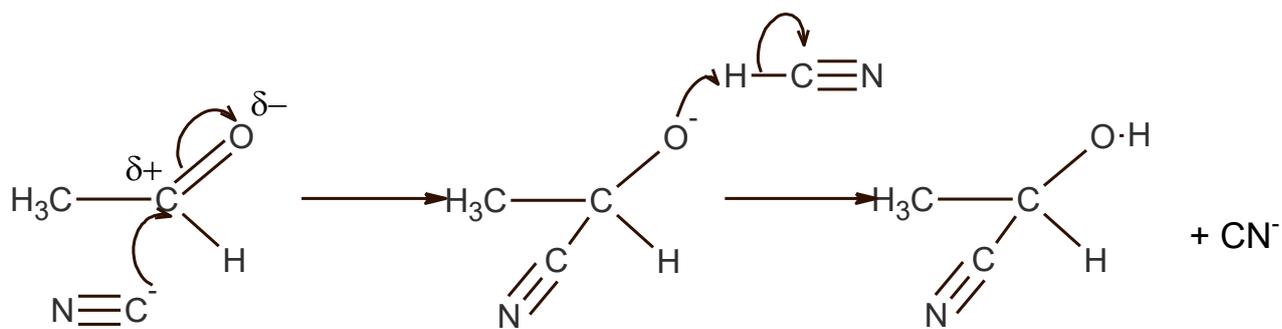
The product of the aromatic Claisen rearrangement is a phenol, so the charge on the anion can be delocalised which stabilises it (1)

(Must be reference to 'anions'; (1) mark awarded for 'stability of anions' if no reference to delocalisation)

[3]

QWC: organisation of information clearly and coherently; use of specialist vocabulary where appropriate [1]

- (d) 1 mark for arrows in first stage; 1 mark for correct intermediate; 1 mark for arrow giving gain of proton in second stage (from HCN or from H^+); 1 mark for bond polarity – max 3 marks; lose 1 if incorrect final structure



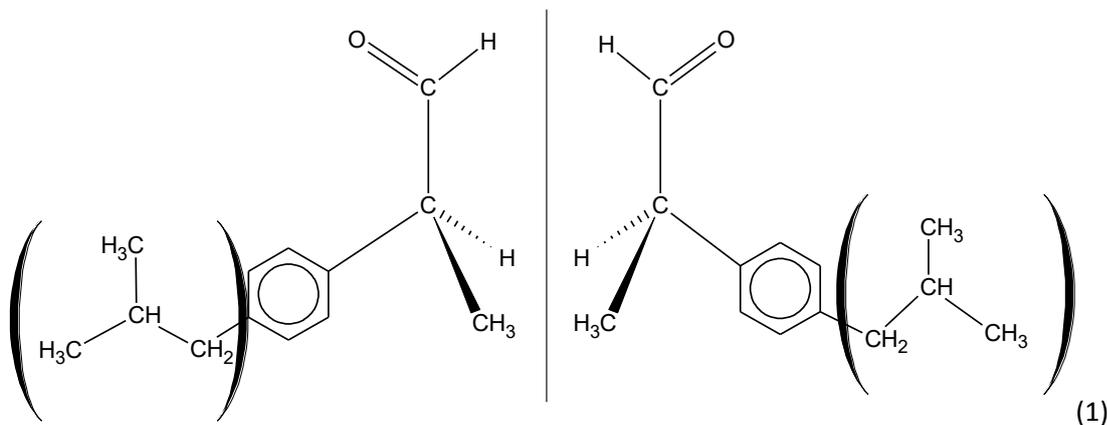
Mechanism: Nucleophilic addition (1)

[4]

Total [14]

Total Section A [40]

- Q.4 (a) $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{Cl}$ (1) AlCl_3 / FeCl_3 (1) Room temperature / in the dark (1) [3]
- (b) (i) 2,4-DNP (1) Orange precipitate (1) [2]
- (ii) Tollen's reagent (1) Silver mirror with **C**, no reaction with **B** (1) [2]
- (c) Optical isomerism is where a molecule and its mirror image are different / non-superimposable (1)
Compound **C** has a chiral centre / 4 different groups attached to one carbon atom (1)



The two isomers rotate the plane of polarised light in opposite directions (1) [4]

QWC: organisation of information clearly and coherently; use of specialist vocabulary where appropriate (1) [1]

- (d) Dilute acid (1) heat (1) hydrolysis (1) [3]
- (e) Acidified potassium dichromate (VI) (1) / heat (1)

One step reactions are generally better as they have a better yield / there is waste in each stage (1)

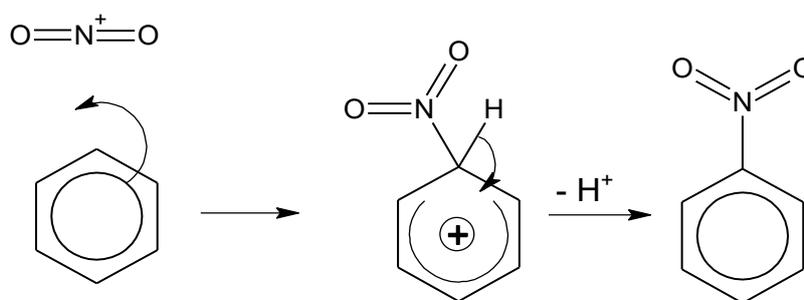
Two step process may be cheaper / use more sustainable reagents/ may give a better yield in this case / produce less harmful waste materials / potassium dichromate may react with other parts of the molecule as well / may be easier to separate product (1)

Do not credit same idea twice e.g. if 'better yield' gains first mark, a different point is required to gain second mark [4]

QWC: selection of a form and style of writing appropriate to purpose and to complexity of subject matter [1]

Total [20]

- Q.5 (a) (i) Both molecules have lone pairs on nitrogen (1)
 The lone pairs can form (coordinate) bonds with H^+ ions (1) [2]
- (ii) Lone pair on N in phenylamine is delocalised over benzene ring (1) therefore less able to accept H^+ (1) [2]
- (iii) I Arrow in first step (1)
 Cation structure in second step (1)
 Arrow in second step (1)

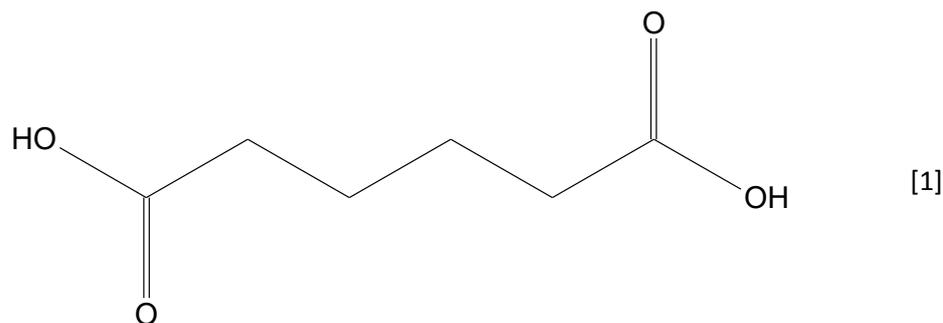


[3]

II (fractional) distillation / steam distillation [1]

III Sn and conc. HCl (1) followed by NaOH (1) [2]

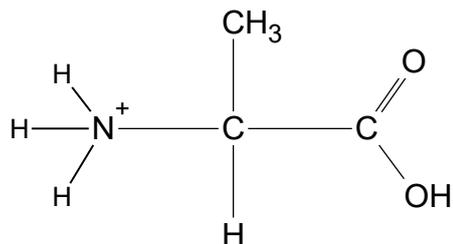
- (b) (i)



[1]

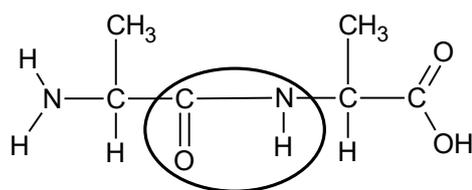
- (ii) Addition polymerisation makes one product only /
 Condensation produces one product plus a small molecule like water (1)
- Addition polymerisation uses one starting material /
 Condensation polymerisation has two different starting materials (1)
- Addition polymerisation involves monomer with one functional group /
 Condensation polymerisation involves monomer with two functional groups
 (1)
- (max 2) [2]

(c) (i)



[1]

(ii)



[2]

(iii) Alanine has strong (electrostatic) forces between the zwitterions (1)

Butanoic acid has hydrogen bonding between molecules /
 electrostatic forces in alanine are stronger than forces in butanoic acid

(1)

[2]

(iv) Soda lime (1) $\text{CH}_3\text{CH}_2\text{NH}_2$ (1)

[2]

Total [20]**Total Section B [40]**



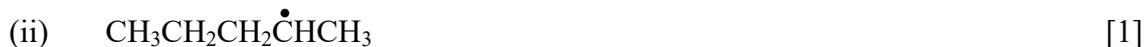
GCE MARKING SCHEME

**CHEMISTRY
AS/Advanced**

SUMMER 2014

GCE CHEMISTRY – CH4
SUMMER 2014 MARK SCHEME

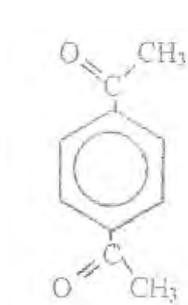
SECTION A



(b) (Anhydrous) aluminium chloride / iron(III) chloride allow AlCl_3 / FeCl_3 [1]

(c) (i) orange / red precipitate [1]

(ii)



(1) —COCH₃ groups in any positions

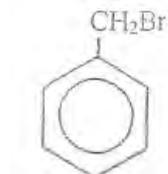
It must contain a C=O group but it is not an aldehyde as it does not react with Tollens' reagent (1) [2]

(d) (i) (Alkaline) potassium manganate(VII) (solution) allow KMnO_4 / MnO_4^- [1]

(ii) Dilute acid allow HCl / H^+ [1]

(iii) Lithium tetrahydridoaluminate(III) / lithium aluminium hydride
allow LiAlH_4 [1]

(iv)

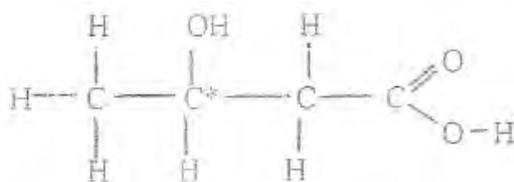


[1]

(e) Only the infrared spectrum of benzoic acid would have a peak at $1650\text{--}1750\text{ cm}^{-1}$ (1)
This is due to the carbonyl group present in the benzoic acid (1) [2]

Total [12]

Q.2 (a)



[1]

(b) (i) Acidified potassium dichromate allow H^+ , $Cr_2O_7^{2-}$ [1]

(ii) I An equimolar mixture of two enantiomers / optical isomers
do not accept 'equal mixture' [1]

II It has no (apparent) effect on the plane of polarised light [1]

(c) (i) But-2-enoic acid; this is because each of the carbon atoms of the double bond has two different groups / atoms
allow reason based on the other isomer [1]

(ii) Any TWO from the following for (1) each
reagent used / temperature / quantities / time of reaction / catalyst / solvent [2]

(d) Reagent(s) KOH / I_2 or NaOCl / KI (1) allow names
Observation Yellow precipitate (1) [2]

(e) The NMR spectrum will consist of two peaks, as there are two discrete 'areas' of protons; these will be seen at between 2.0 to 2.5 (CH_3) and between 2.5 to 3.0 (CH_2) (1)
The peak area ratio will be 3:2 for the CH_3 and CH_2 protons respectively (1)
There will be no splitting of either signal as the protons causing these signals are not bonded directly to other carbon atoms that also have protons (1)

1 max if only one peak described correctly [3]

QWC Legibility of text; accuracy of spelling, punctuation and grammar;
clarity of meaning. [1]

Total [13]

Q.3 (a) (i) 2 mol of ethanol gives 1 mol of ethoxyethane (1)

$$\text{Moles of ethanol} = \frac{69}{46} = 1.5$$

$$\therefore \text{Moles of ethoxyethane if theoretical yield} = 0.75$$

$$\therefore \text{Moles of ethoxyethane if 45\% yield} = 0.75 \times 0.45 = 0.34 \quad (1)$$

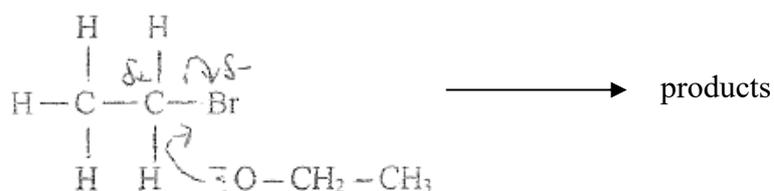
$$\text{Mass of ethoxyethane} = 0.34 \times 74 = 25\text{g} \quad (1) \text{ allow error carried forward}$$

[3]

(ii) Ethene / C₂H₄

[1]

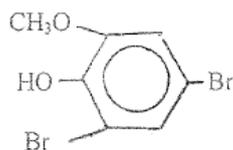
(iii)



(1) for correct curly arrows (1) for correct δ^+ and δ^- [2]

(iv) They need to have an N-H / O-H / F-H bond / a highly electronegative atom bonded to hydrogen [1]

(b) (i) For example



[1]

Accept any polybrominated species

Do not accept a monobrominated species

(ii) Bromine decolorised / orange to colourless / white solid [1]

(c) Reagent Iron(III) chloride solution / FeCl₃ (1)

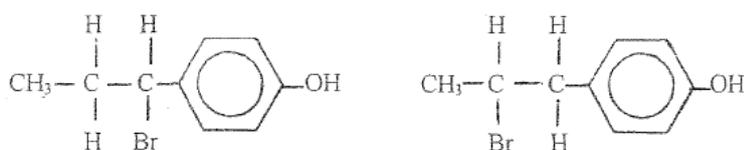
Observation Purple coloration / solution (1)

[2]

(d) (i) C₁₀H₁₂O₁

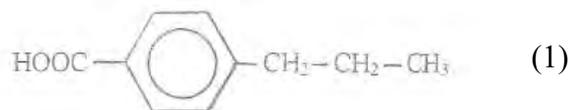
[1]

(ii)



[1]

(e) Displayed formula, for example



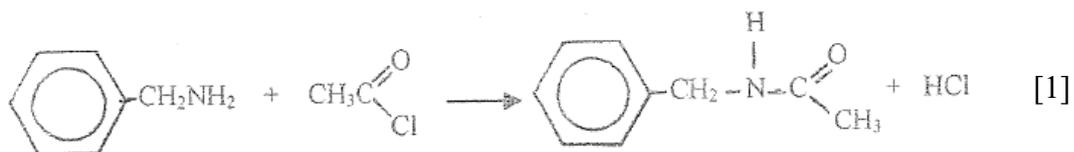
Functional group carboxylic acid (1)

[2]

Total [15]

SECTION B

- Q.4** (a) (i) (Fractional) distillation / (preparative) gas chromatography / HPLC / TLC column chromatography / solvent extraction [1]
- (ii) the fragmentation pattern would be different / valid examples given [1]
- (iii) I



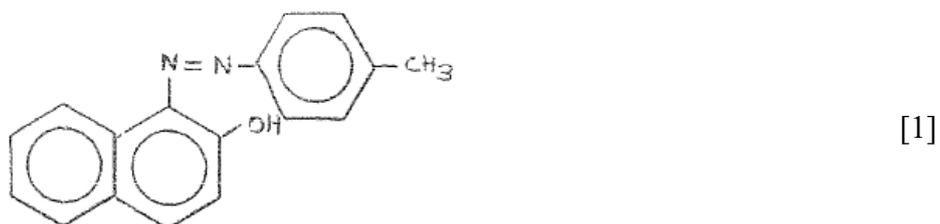
- II Heated electrically / by a naked flame with a water bath (1)
 Add compound **G** to the ethanol until the hot ethanol will (just) not dissolve any more solute (1)
 Filter hot (1)
 Allow to cool (1)
 Filter (1)
 Dry in air / window sill / $< 60^\circ\text{C}$ in an oven (1) [5]

Maximum 4 out of 5 total if second marking point not given
 Note 5 marks maximum here

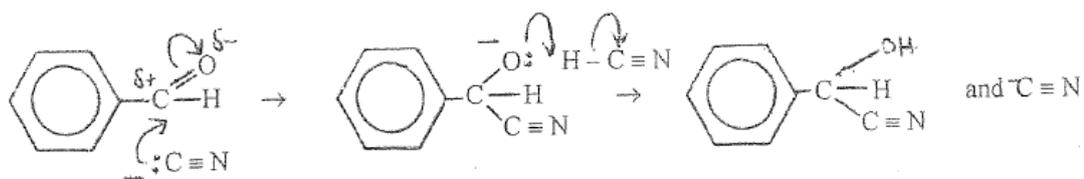
QWC Information organised clearly and coherently, using specialist vocabulary where appropriate [1]

- (iv) I The amine is reacted with sodium nitrite / HCl(aq) or nitrous acid (1)
 at a temperature of $< 10^\circ\text{C}$ (1) [2]

II



- (b) (i) Nucleophilic addition (1)



Accept a mechanism that shows HCN polarisation and nucleophilic addition as a concerted process

polarisation / charges shown (1) curly arrows on first structure (1)

regeneration of $^-\text{C}\equiv\text{N}$ or capture of H^+ and curly arrow (1)

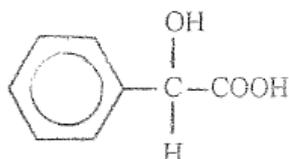
[4]

- (ii) Chromophores (1)

The colour will be black (1) as the compound absorbs blue / other colours (1)

[3]

- (iii)



[1]

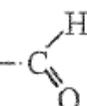
Total [20]

Q.5 (a)

	C 71.3	H 9.6	∴ O 19.1 (1)
÷ by A_r	$\frac{71.3}{12} = 5.94$	$\frac{9.6}{1.0} = 9.6$	$\frac{19.1}{16} = 1.193$
÷ smallest	$\frac{5.94}{1.193} = 5$	$\frac{9.6}{1.193} = 8$	$\frac{1.193}{1.193} = 1$ (1)

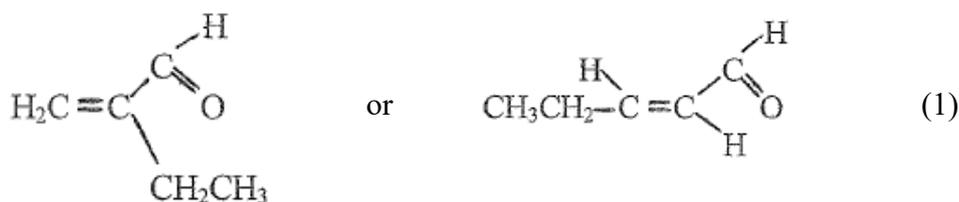
Only one oxygen atom per molecule

∴ Molecular formula is C_5H_8O (1)

Silver mirror produced ∴  present (1)

Ion m/z 29 suggests ethyl group present / CH_3CH_2 (1)

Structure must be



[6]

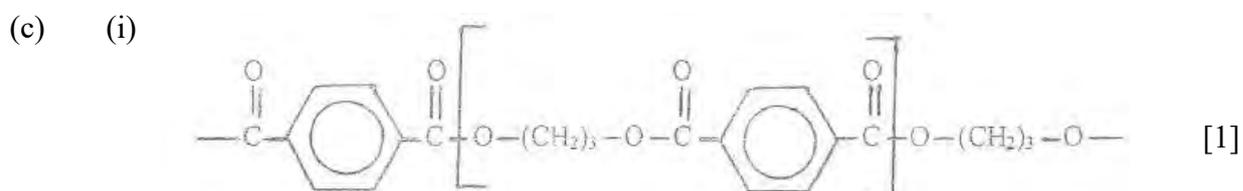
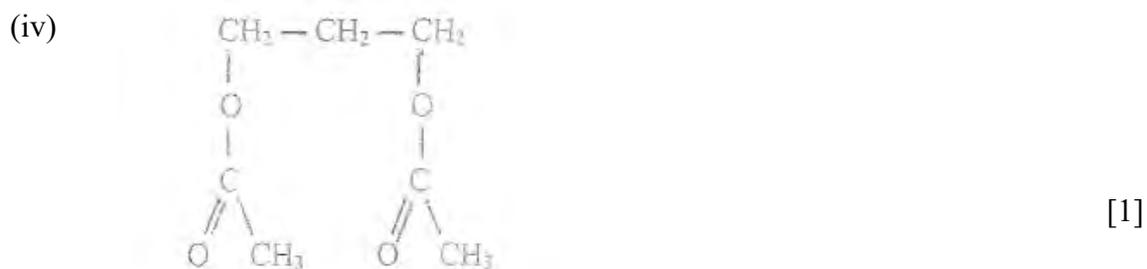


(ii) Total peak areas $26 + 13 + 46 = 85$

% propene = $\frac{13 \times 100}{85} = 15.3$ [1]

(iii) Any THREE points for (1) each [3]

e.g. can it run at a lower temperature (reducing energy costs)
 is the yield comparable / better than the yield from the propene process
 is the time taken comparable / better than used in the propene process
 is there a continued availability of starting materials
 can the product be easily / better separated from the reaction mixture
 is relatively more expensive equipment needed
 is it a batch or continuous process



- (ii) The production of PTT is an example of condensation polymerisation (1)
 The production of poly(propene) is an example of addition polymerisation (1)
 Condensation polymerisation needs bifunctional compounds / COOH,OH etc (1)

Addition polymerisation needs a >C=C< present in the monomer (1)

Addition polymerisation has an atom economy of 100% (1)

Condensation polymerisation has an atom economy of < 100%
 (as a co-product is formed) (1) [6]

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter [1]

Total [20]