

**MARK SCHEME for the October/November 2011 question paper
for the guidance of teachers**

9701 CHEMISTRY

9701/21

Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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Page 2	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9701	21

- 1 (a) (i) mass of C = $\frac{12 \times 0.352}{44} = 0.096\text{g}$ (1)
- $n(\text{C}) = \frac{0.096}{12} = 0.008$ (1)
- (ii) mass of H = $\frac{2 \times 0.144}{18} = 0.016\text{g}$ (1)
- $n(\text{H}) = \frac{0.016}{1} = 0.016$ (1)
- (iii) mass of oxygen = $0.240 - (0.096 + 0.016) = 0.128\text{g}$ (1)
- $n(\text{O}) = \frac{0.128}{16} = 0.008$ (1)
- allow ecf at any stage [6]
- (b) C : H : O = 0.008 : 0.016 : 0.008 = 1:2:1
- allow C : H : O = $\frac{0.096}{12} : \frac{0.016}{1} : \frac{0.128}{16} = 1:2:1$
- gives CH_2O (1) [1]
- (c) (i) $M_r = \frac{mRT}{pV} = \frac{0.148 \times 8.31 \times 333}{1.01 \times 10^5 \times 67.7 \times 10^{-6}}$ (1)
- = 59.89
- allow 59.9 or 60 (1)
- (ii) $\text{C}_2\text{H}_4\text{O}_2$ (1) [3]
- (d) $\text{CH}_3\text{CO}_2\text{H}$ (1)
- HCO_2CH_3 (1) [2]
- (e) the only products of the reaction are the two oxides H_2O and CO_2 and copper (1) [1]

[Total: 13]

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- 2 (a) $S(g) \rightarrow S^+(g) + e^-$
correct equation (1)
correct state symbols (1) [2]

- (b) **from Na to Ar,**
electrons are added to the same shell/have same shielding (1)
electrons are subject to increasing nuclear charge/proton number (1)
electrons are closer to the nucleus **or** atom gets smaller (1) [3]

- (c) (i) **Mg and Al**
in Mg outermost electron is in 3s **and**
in Al outermost electron is in 3p (1)

3p electron is at higher energy **or**
is further away from the nucleus **or**
is more shielded from the nucleus (1)

- (ii) **S and P**
for S one 3p orbital has paired electrons **and**
for P 3p sub-shell is singly filled (1)

paired electrons repel (1) [4]

- (d) (i) and (ii)

element	Na	Mg	Al	Si	P	S
conductivity	high	high	—	moderate	low	low
melting point	low	high	—	high	low	low

(1) (1) (1) (1) (1)

one mark for each correct column [5]

- (e) germanium/Ge (1) [1]

[Total: 15]

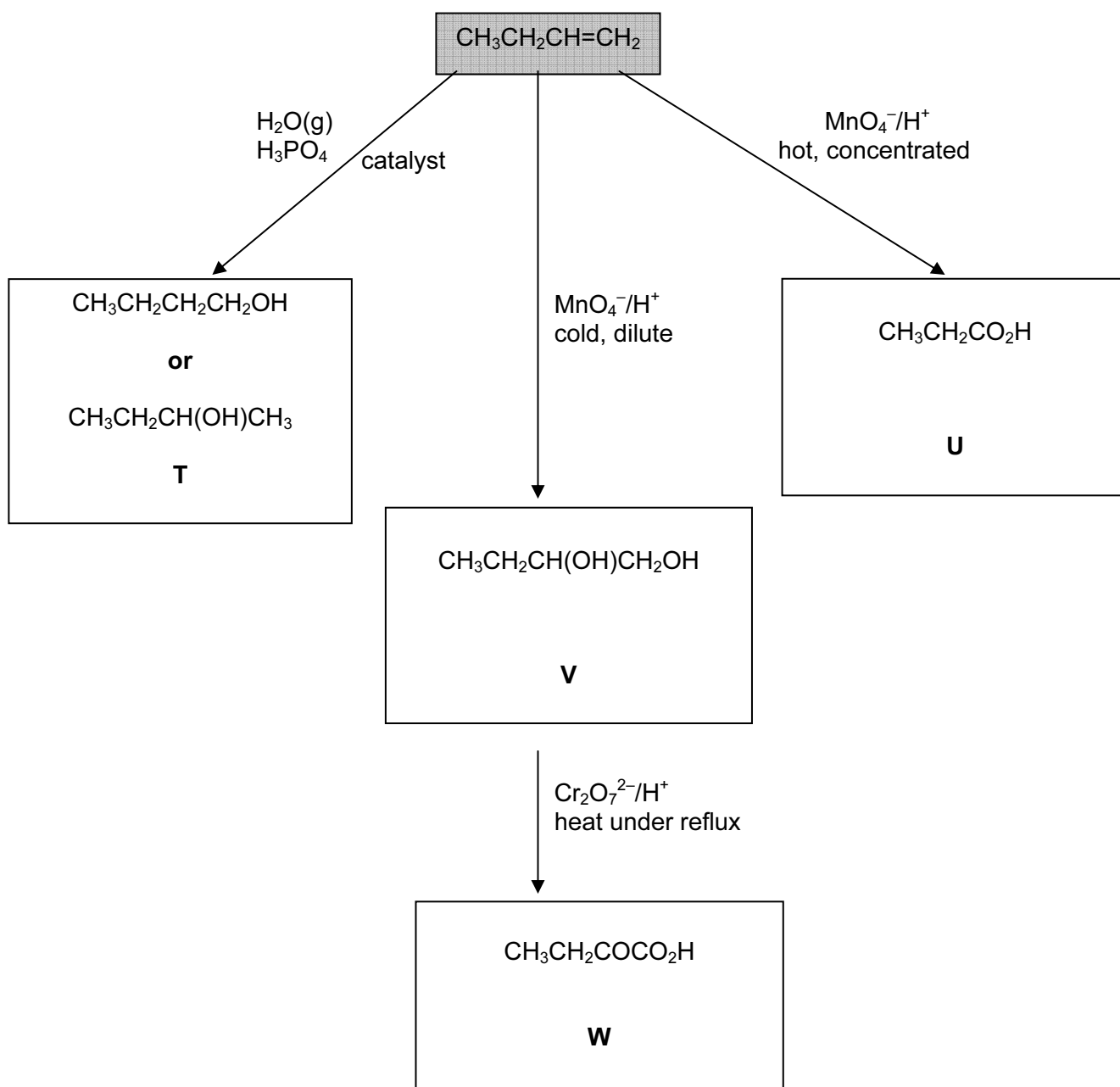
Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
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- 3 (a)** the overall enthalpy change/energy change/ ΔH for a reaction (1)
- is independent of the route taken **or**
 is independent of the number of steps involved
 provided the initial and final conditions are the same (1) [2]
- (b) (i)** $\text{K}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{KCl} + \text{H}_2\text{O} + \text{CO}_2$ (1)
- (ii)** heat produced = $m \times c \times \delta T = 30.0 \times 4.18 \times 5.2$
 $= 652.08 \text{ J per } 0.0200 \text{ mol of } \text{K}_2\text{CO}_3$ (1)
- (iii)** $0.020 \text{ mol } \text{K}_2\text{CO}_3 \equiv 652.08 \text{ J}$
 $1 \text{ mol } \text{K}_2\text{CO}_3 \equiv \frac{652.08 \times 1}{0.0200} = 32604 \text{ J}$
 enthalpy change = $-32.60 \text{ kJmol}^{-1}$ (1)
- (iv)** to prevent the formation of KHCO_3 **or**
 to ensure complete neutralisation (1) [4]
- (c) (i)** $\text{KHCO}_3 + \text{HCl} \rightarrow \text{KCl} + \text{H}_2\text{O} + \text{CO}_2$ (1)
- (ii)** heat absorbed = $m \times c \times \delta T = 30.0 \times 4.18 \times 3.7$
 $= 463.98 \text{ J per } 0.0200 \text{ mol of } \text{KHCO}_3$ (1)
- (iii)** $0.020 \text{ mol } \text{KHCO}_3 \equiv 463.98 \text{ J}$
 $1 \text{ mol } \text{KHCO}_3 \equiv \frac{463.98 \times 1}{0.0200} = 23199 \text{ J}$
 enthalpy change = $+23.20 \text{ kJmol}^{-1}$ (1) [3]
- (d)** $\Delta H = 2 \times (+23.20) - (-32.60) = +79.00 \text{ kJ mol}^{-1}$ (2) [2]

[Total: 11]

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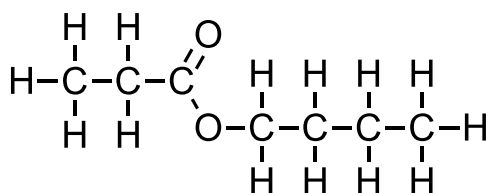
4 (a)



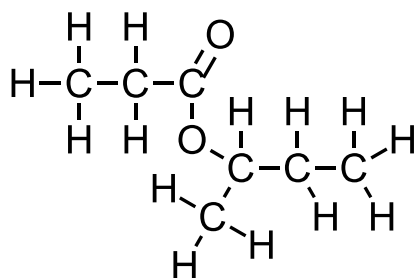
correct **T**
 correct **U**
 correct **V**
 correct > CO group in **W**
 correct –CO₂H group in **W**

(1)
 (1)
 (1)
 (1)
 (1) [5]

(b) T + U



or



correct structures
correctly displayed ester group

(1)
(1) [2]

[Total: 7]

5	(a)	(i)	1	primary	(1)
				alcohol not hydroxyl	(1)
			2	aldehyde not carbonyl	(1)

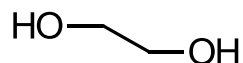
(ii)

test 1			
reagent	Na	$\text{PCl}_3/\text{PCl}_5/\text{PBr}_3$	$\text{RCO}_2\text{H}/\text{H}^+$
observation	gas/ H_2 /effervescence/ fizzing	HCl/HBr steamy fumes	fruity smell
test 2			
reagent	Tollens' reagent	Fehling's reagent	2,4-dinitro- phenylhydrazine
observation	Ag mirror/silver/ black ppt	brick-red ppt red ppt	orange/red/yellow ppt/solid

only award the observation mark if reagent is correct (4) [7]

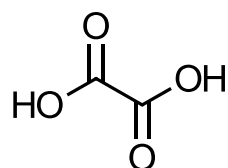
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(b) (i)



(1)

(ii)



(1) [2]

5 (c)

route	starting compound	first reagent	intermediate X	second reagent	intermediate Y	third reagent	final compound
A/1	HOCH ₂ CHO	PCl ₃ PCl ₅ SOCl ₂ etc.	ClCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	ClCH ₂ CO ₂ H	NH ₃	H ₂ NCH ₂ CO ₂ H
A/2	HOCH ₂ CHO	HBr P/Br ₂ etc.	BrCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	BrCH ₂ CO ₂ H	NH ₃	H ₂ NCH ₂ CO ₂ H
B/1	HOCH ₂ CHO	PCl ₃ PCl ₅ SOCl ₂ etc.	ClCH ₂ CHO	NH ₃	H ₂ NCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	H ₂ NCH ₂ CO ₂ H
B/2	HOCH ₂ CHO	HBr P/Br ₂ etc.	BrCH ₂ CHO	NH ₃	H ₂ NCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	H ₂ NCH ₂ CO ₂ H
C	HOCH ₂ CHO	Tollens' or Fehling's reagents	HOCH ₂ CO ₂ H	KBr/conc. H ₂ SO ₄	BrCH ₂ CO ₂ H	NH ₃	H ₂ NCH ₂ CO ₂ H
mark		(1)	(1)	(1)	(1)	(1)	

[5]

[Total: 14]

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- $= 59.89$
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- (c) (i) **Mg and Al**
in Mg outermost electron is in 3s **and**
in Al outermost electron is in 3p (1)

3p electron is at higher energy **or**
is further away from the nucleus **or**
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for S one 3p orbital has paired electrons **and**
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- (d) (i) and (ii)

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one mark for each correct column [5]

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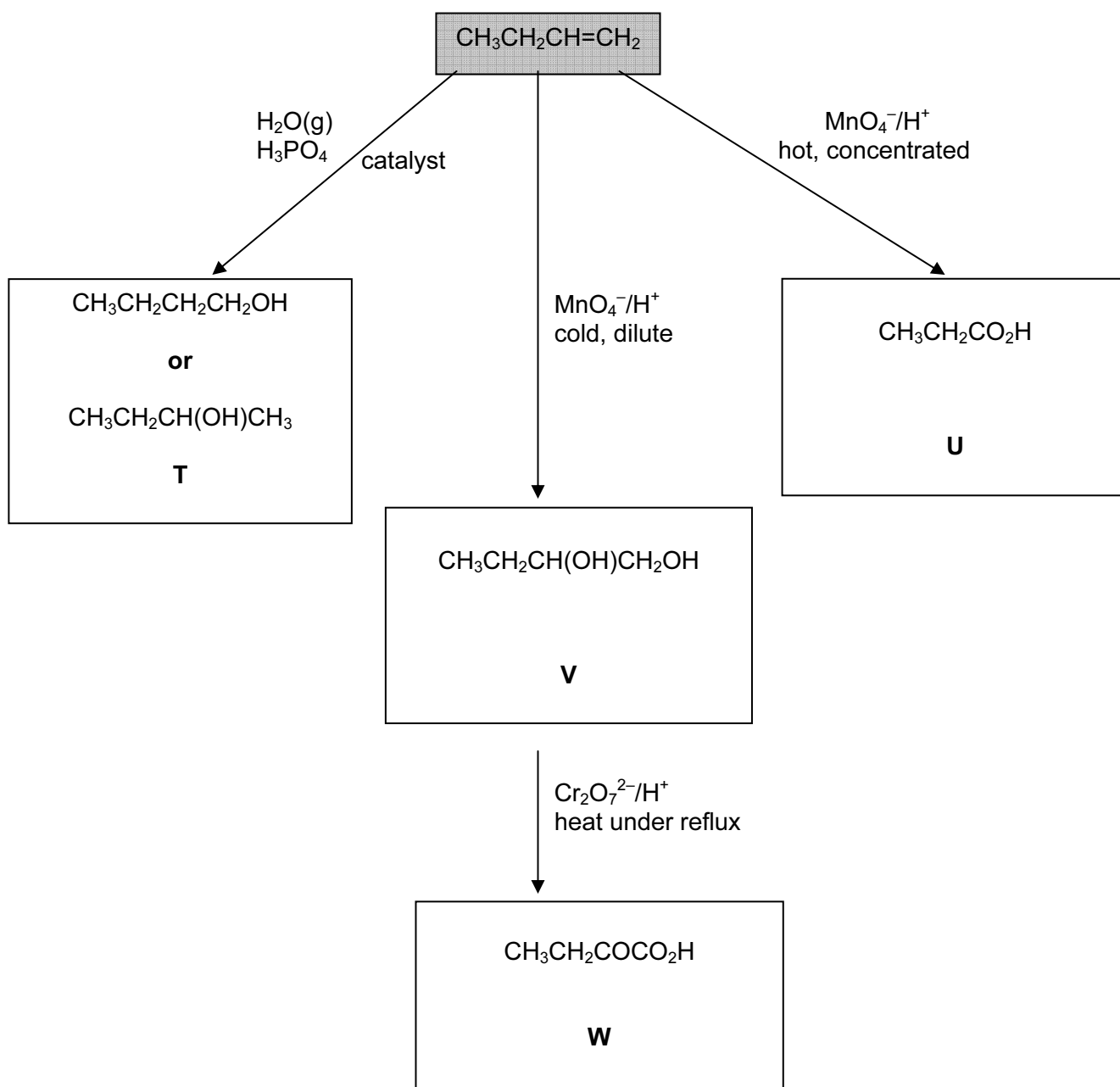
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[Total: 11]

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4 (a)



correct **T**

correct **U**

correct **V**

correct > CO group in **W**

correct –CO₂H group in **W**

(1)

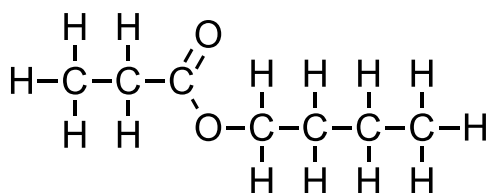
(1)

(1)

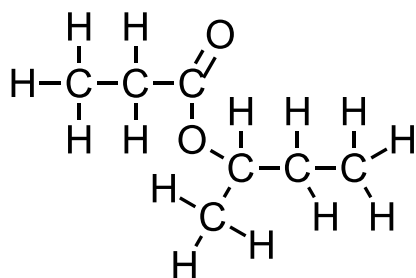
(1)

(1) [5]

(b) T + U



or



correct structures
correctly displayed ester group

(1)
(1) [2]

[Total: 7]

5	(a)	(i)	1	primary alcohol not hydroxyl	(1)
					(1)
			2	aldehyde not carbonyl	(1)

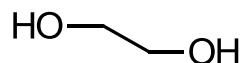
(ii)

test 1			
reagent	Na	$\text{PCl}_3/\text{PCl}_5/\text{PBr}_3$	$\text{RCO}_2\text{H}/\text{H}^+$
observation	gas/ H_2 /effervescence/ fizzing	HCl/HBr steamy fumes	fruity smell
test 2			
reagent	Tollens' reagent	Fehling's reagent	2,4-dinitro- phenylhydrazine
observation	Ag mirror/silver/ black ppt	brick-red ppt red ppt	orange/red/yellow ppt/solid

only award the observation mark if reagent is correct (4) [7]

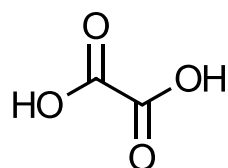
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(b) (i)



(1)

(ii)



(1) [2]

5 (c)

route	starting compound	first reagent	intermediate X	second reagent	intermediate Y	third reagent	final compound
A/1	HOCH ₂ CHO	PCl ₃ PCl ₅ SOCl ₂ etc.	ClCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	ClCH ₂ CO ₂ H	NH ₃	H ₂ NCH ₂ CO ₂ H
A/2	HOCH ₂ CHO	HBr P/Br ₂ etc.	BrCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	BrCH ₂ CO ₂ H	NH ₃	H ₂ NCH ₂ CO ₂ H
B/1	HOCH ₂ CHO	PCl ₃ PCl ₅ SOCl ₂ etc.	ClCH ₂ CHO	NH ₃	H ₂ NCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	H ₂ NCH ₂ CO ₂ H
B/2	HOCH ₂ CHO	HBr P/Br ₂ etc.	BrCH ₂ CHO	NH ₃	H ₂ NCH ₂ CHO	K ₂ Cr ₂ O ₇ /H ⁺ KMnO ₄ /H ⁺ KMnO ₄ /OH ⁻ Tollens' or Fehling's reagents	H ₂ NCH ₂ CO ₂ H
C	HOCH ₂ CHO	Tollens' or Fehling's reagents	HOCH ₂ CO ₂ H	KBr/conc. H ₂ SO ₄	BrCH ₂ CO ₂ H	NH ₃	H ₂ NCH ₂ CO ₂ H
mark		(1)	(1)	(1)	(1)	(1)	

[5]

[Total: 14]

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- 1 (a) same proton number/atomic number (1)
different mass number/nucleon number (1) [2]

(b) $A_r = \frac{(32 \times 95.00) + (33 \times 0.77) + (34 \times 4.23)}{100}$ (1)

$$= \frac{3040 + 25.41 + 143.82}{100} = \frac{3209.23}{100}$$

which gives $A_r = 32.09$ (1) [2]

(c)

	number of		
isotopes	protons	neutrons	electrons
^{213}Po	84	129	84
^{232}Th	90	142	90

allow **one mark** for each correct column
if there are no 'column' marks,
allow **maximum one mark** for a correct row

(3 × 1) [3]

- (d) (i) nucleon no. is 228 (1)
proton no. is 88 (1)

(ii) Ra **not** radium (1) [3]

[Total: 10]

2 (a) (i) mass of C = $\frac{12 \times 1.32}{44} = 0.36\text{g}$ (1)

$$n(\text{C}) = \frac{0.36}{12} = 0.03$$
 (1)

(ii) mass of H = $\frac{2 \times 0.54}{18} = 0.06\text{ g}$ (1)

$$n(\text{H}) = \frac{0.06}{1} = 0.06$$
 (1)

- (iii) yes **because** 0.03 mol of C are combined with 0.06 mol of H **or**
C : H ratio is 1 : 2 **or**
empirical formula is CH₂ (1) [5]

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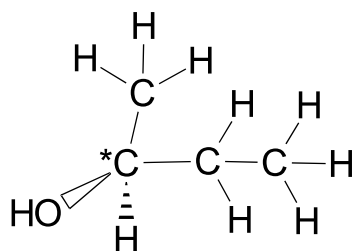
(b) (i) $C : H : O = \frac{64.86}{12} : \frac{13.50}{1} : \frac{21.64}{16}$ (1)

$$= 5.41 : 13.50 : 1.35$$

$$= 4 : 10 : 1$$

gives $C_4H_{10}O$ (1)

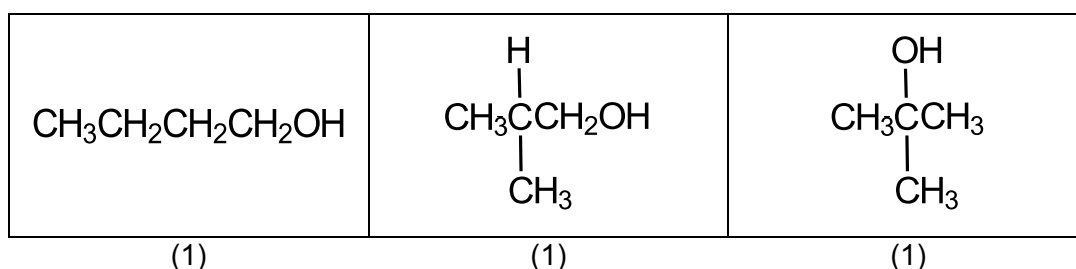
(ii)



correct compound **and** correct chiral C^* (1)

correct mirror object/ mirror image relationship in 3D (1)

(iii)



[7]

[Total: 12]

3 (a) $C(g) \rightarrow C^+(g) + e^-$ (1)
correct equation (1)
correct state symbols (1) [2]

(b) (i) **Na and Mg** (1)
Mg has greater nuclear charge/more protons than Na (1)

in both atoms, the 3s electrons are in the same orbital/
same energy level/same shell (1)

(ii) **Mg and Al** (1)
in Al outermost electron is in 3p rather than 3s (1)

3p electron is at higher energy **or**
is further away/is more shielded from nucleus (1)

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- (iii) **He and Ne**
both He and Ne have the highest nuclear charges in their Period (1)
- (iv) **He, Ne, and Ar**
going down the group,
valence/outer shell electrons are farther from the nucleus (1)
there is greater shielding (1)
attraction between valence electrons and nucleus is less **or**
effective nuclear charge is less (1) [8]
- (c) (i) **from Na to Cl**
increased nuclear charge/nuclear attraction (1)
- (ii) cation has fewer electrons than atom **or**
cation has lost outer electrons **or**
cation has fewer shells (1)
but cation has same nuclear charge as atom **or**
proton number is the same (1) [3]

3 (d) ignore any state symbols

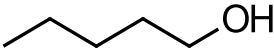
MgO(s)	+	NaOH(aq)	→	NO REACTION	(1)		
MgO(s)	+	2HCl(aq)	→	MgCl ₂ + H ₂ O	(1)		
Al ₂ O ₃ (s)	+	2NaOH(aq)	+	3H ₂ O(l)	→	2NaAl(OH) ₄ or	(1)
Al ₂ O ₃ (s)	+	2NaOH(aq)	+	H ₂ O(l)	→	2NaAlO ₂ + 2H ₂ O or	
Al ₂ O ₃ (s)	+	6NaOH(aq)	+	3H ₂ O(l)	→	2Na ₃ Al(OH) ₆	
Al ₂ O ₃ (s)	+	6HCl(aq)	→	2AlCl ₃ + 3H ₂ O or	(1)		
Al ₂ O ₃ (s)	+	6HCl(aq)	→	Al ₂ Cl ₆ + 3H ₂ O			
SO ₂ (g)	+	NaOH(aq)	→	NaHSO ₃ or	(1)		
SO ₂ (g)	+	2NaOH(aq)	→	Na ₂ SO ₃ + H ₂ O			
SO ₂ (g)	+	HCl(aq)	→	NO REACTION	(1)		

[6]

[Total: 19]

4 (a) (i) C₂H₅O (1)

(ii)



(1) [2]

Page 5	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9701	23

- (b) (i) functional group isomerism
or structural isomerism (1)

do **not** allow 'functional isomerism' or positional isomerism

(ii)

compound	type of isomerism
P	<i>cis-trans</i> or geometrical
T	optical

(1 + 1) [3]

- (c) (i) dehydration/elimination (1)

- (ii) conc. H_2SO_4 / P_4O_{10} / Al_2O_3 / H_3PO_4 / pumice (1)

- (iii) $\text{CH}_2=\text{CHCH}=\text{CH}_2$

allow $\text{CH}_2=\text{C}=\text{CHCH}_3$ (1) [3]

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

- (ii) steam with H_3PO_4 catalyst or
conc. H_2SO_4 then water (1 + 1)

only allow condition mark if reagent mark has been given

- (iii) $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ or
 $\text{MnO}_4^-/\text{H}^+$ (1) [4]

[Total: 12]

- 5 (a) **V** is HCHO (1) [1]

- (b) (i) ester (1)

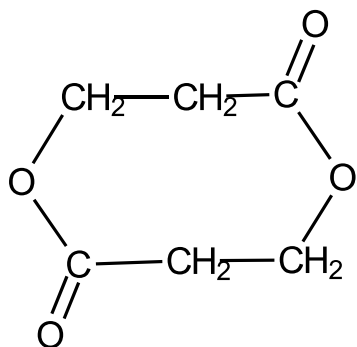
- (ii) **W** is HCO_2CH_3 (1) [2]

- (c) (i) **X** is $\text{HOCH}_2\text{CH}_2\text{CO}_2\text{H}$ (1)

- (ii) **Y** is $\text{HO}_2\text{CCH}_2\text{CO}_2\text{H}$ (1) [2]

Page 6	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9701	23

(d) (i) Z is



(1)

(ii) esterification **or**
dehydration **or**
elimination **or**
condensation

(1) [2]

[Total: 7]