

MARK SCHEME for the October/November 2012 series

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	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2012	9701	21

- 1 (a) ZnCO_3 Zn(OH)_2 ZnO
not Zn or other compounds of Zn (any 2) [2]
- (b) (i) to ensure all of the water of crystallisation had been driven off **or**
to be at constant mass (1)
- (ii) mass of $\text{ZnSO}_4 = 76.34 - 74.25 = 2.09 \text{ g}$ (1)
- $M_r \text{ ZnSO}_4 = 65.4 + 32.1 + (4 \times 16.0) = 161.5$
- allow use of $\text{Zn} = 65$ and/or $\text{S} = 32$ to give values between 161 and 161.5 (1)
- $n(\text{ZnSO}_4) = \frac{2.09}{161.5} = 0.01294 = 1.29 \times 10^{-2}$
- $\text{ZnSO}_4 = 161$ gives 1.30×10^{-2} (1)
- (iii) mass of H_2O driven off $= 77.97 - 76.34 = 1.63 \text{ g}$ (1)
- $n(\text{H}_2\text{O}) = \frac{1.63}{18} = 0.0905 = 9.1 \times 10^{-2}$ (1)
- (iv) $1.29 \times 10^{-2} \text{ mol ZnSO}_4$ are combined with $9.1 \times 10^{-2} \text{ mol H}_2\text{O}$
- 1 mol ZnSO_4 is combined with $\frac{9.1 \times 10^{-2}}{1.29 \times 10^{-2}}$
- $= 7.054 \approx 7 \text{ mol H}_2\text{O}$
- answer must be expressed as a whole number
allow ecf on candidate's answers to (b)(ii) and (b)(iii) (1) [7]
- (c) (i) $n(\text{Zn}) = n(\text{CH}_3\text{CO}_2)_2\text{Zn} \cdot 2\text{H}_2\text{O}$ (1)
- $n(\text{Zn}) = \frac{0.015}{65.4} = 2.290 \times 10^{-4}$
- $= 2.29 \times 10^{-4}$ (1)
- mass of crystals $= 2.29 \times 10^{-4} \times 219.4 = 0.0502655 \text{ g}$
 $= 0.05 \text{ g} = 50 \text{ mg}$ (1)
- (ii) concentration of $(\text{CH}_3\text{CO}_2)_2\text{Zn} \cdot 2\text{H}_2\text{O} = \frac{2.29 \times 10^{-4}}{0.005} = 0.0458$
- $= 4.58 \times 10^{-2} \text{ mol dm}^{-3}$ (1)
- allow correct answers if $\text{Zn} = 65$ is used [4]

[Total: 13]

Page 3	Mark Scheme	Syllabus	Paper
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- 2 (a) (i) thermal stability decreases down Group VII (1)
- (ii) from Cl to I, atomic size increases **or**
the bonding pair is further from the nucleus of X **or**
H—X bond becomes longer **or**
smaller orbital overlap occurs (1)
hence H—X bond strength decreases down Group VII (1) [3]

(b) $K_c = \frac{[HI]^2}{[H_2] \times [I_2]}$ (1)

no units – must be clearly stated (1) [2]

- (c) (i) no change (1)
 K_c has no units **or**
same no. of molecules / moles each side of equilibrium (1)
- (ii) equilibrium moves to RHS (1)
 K_c increases with decreasing temperature **or**
forward reaction is exothermic **or**
reverse reaction is endothermic (1) [4]

(d)

	$H_2(g)$	+	$I_2(g)$	$\rightleftharpoons$	$2HI(g)$	
initial moles	0.02		0.02		0	
equil. moles	$(0.02 - y)$		$(0.02 - y)$		$2y$	(1)
equil. conc/mol dm ⁻³	$\frac{(0.02 - y)}{1}$		$\frac{(0.02 - y)}{1}$		$\frac{2y}{1}$	

$$K_c = \frac{HI^2}{[H_2] \times [I_2]} = \frac{(2y)^2}{(0.02 - y)^2} = 59 \quad (1)$$

$$\frac{2y}{(0.02 - y)} = \sqrt{59} = 7.7$$

$$2y = (7.7 \times 0.02) - 7.7y$$

$$9.7y = 0.154$$

$$\text{gives } y = \frac{0.154}{9.7} = 0.0159 = 0.016 \quad (1)$$

at equilibrium

$$n(HI) = 2 \times 0.016 = 0.032 \text{ and}$$

$$n(H_2) = n(I_2) = (0.02 - 0.016) = 0.004 \quad (1)$$

allow ecf where possible [4]

[Total: 13]

Page 4	Mark Scheme	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2012	9701	21

- 3 (a) (i) $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ **or**
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$
state symbols required (1)
- (ii) **pressure** between 60 and 250 atm **or**
between 60×10^5 Pa and 250×10^5 Pa (1)
- temperature** between 300 and 550 °C (1)
- catalyst** iron / iron oxide (1)
- (iii) manufacture of HNO_3 / as a cleaning agent / refrigerant / fertiliser / manufacture of fertilisers / explosives / to remove SO_2 from combustion products of hydrocarbon fuels (1) [5]
- (b) (i) NH_4Cl and $\text{Ca}(\text{OH})_2$
both formulae required (1)
- (ii) $2\text{NH}_4\text{Cl} + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCl}_2 + 2\text{NH}_3 + 2\text{H}_2\text{O}$ **or**
 $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$
correct products (1)
correctly balanced equation (1)
- (iii) CaO (1)
it is not an acid / it is basic / it does not react with NH_3 **or**
both P_2O_5 / P_4O_{10} **and** H_2SO_4 are acidic / react with NH_3 (1) [5]
- (c)
- $$\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{N}: \\ | \\ \text{H} \end{array} + \text{H}^+ \longrightarrow \left[\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{N} \rightarrow \text{H} \\ | \\ \text{H} \end{array} \right]^+$$
- correct displayed eqn.,
with positive charge clearly shown (1)
lone pair on NH_3 (1)
co-ordinate / dative bond clearly shown (1) [3]

[Total: 13]

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4 (a) (i)

reaction	organic compound	reagent	structural formulae of organic products
A	$(\text{CH}_3)_3\text{COH}$	$\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ heat under reflux	no reaction
B	$\text{CH}_3\text{CH}_2\text{CHO}$	Fehling's reagent warm	$\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$ or $\text{CH}_3\text{CH}_2\text{CO}_2^-$
C	$\text{HCO}_2\text{CH}(\text{CH}_3)_2$	NaOH(aq) warm	HCO_2Na or HCO_2^- $(\text{CH}_3)_2\text{CHOH}$
D	$\text{CH}_2=\text{CHCHO}$	NaBH_4	$\text{CH}_2=\text{CHCH}_2\text{OH}$
E	$(\text{CH}_3)_3\text{COH}$	NaBH_4	no reaction
F	$\text{CH}_3\text{CH}_2\text{COCH}_3$	$\text{MnO}_4^-/\text{H}^+$ heat under reflux	no reaction

each correct answer gets (1)

(7 × 1)

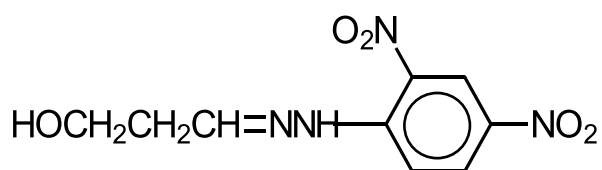
(ii)

reaction	colour at the beginning of the reaction	colour at the end of the reaction
B	blue	brick red

each correct answer gets 1

(1 + 1 + 1) [10]

(b) (i)



(1)

(ii) red or orange

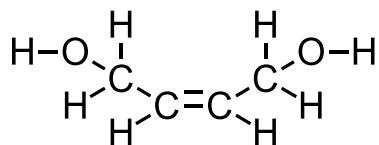
(1) [2]

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- 5 (a) (i) carboxylic acid **or** alcohol present **or** carboxylic acid **and** alcohol present **not** acid **or** carboxyl **or** hydroxyl (1)
- (ii) carboxylic acid **not** present **or** only alcohol present (1)
- (iii) alkene **or** $>C=C<$ present (1) [3]

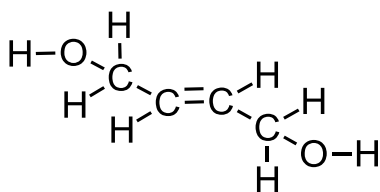
(b) (i)



each correct structure gets (1)

(4 × 1)

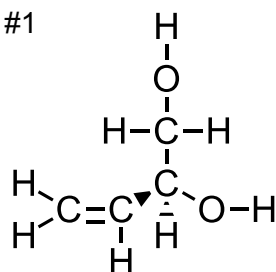
- (ii) pair 1 geometrical **or** *cis-trans* **or** *E/Z* isomerism (1)



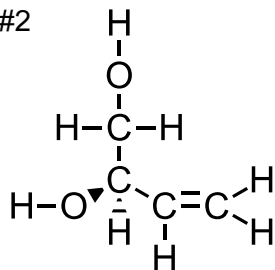
pair 2 optical isomerism – accept chiral compounds

(1) [6]

#1



#2



[Total: 9]

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(d)

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between 60×10^5 Pa and 250×10^5 Pa (1)
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correct products (1)
correctly balanced equation (1)
- (iii) CaO (1)
it is not an acid / it is basic / it does not react with NH_3 **or**
both P_2O_5 / P_4O_{10} **and** H_2SO_4 are acidic / react with NH_3 (1) [5]
- (c)
- $$\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{N}: \\ | \\ \text{H} \end{array} + \text{H}^+ \longrightarrow \left[\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{N} \rightarrow \text{H} \\ | \\ \text{H} \end{array} \right]^+$$
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C	$\text{HCO}_2\text{CH}(\text{CH}_3)_2$	NaOH(aq) warm	HCO_2Na or HCO_2^- $(\text{CH}_3)_2\text{CHOH}$
D	$\text{CH}_2=\text{CHCHO}$	NaBH_4	$\text{CH}_2=\text{CHCH}_2\text{OH}$
E	$(\text{CH}_3)_3\text{COH}$	NaBH_4	no reaction
F	$\text{CH}_3\text{CH}_2\text{COCH}_3$	$\text{MnO}_4^-/\text{H}^+$ heat under reflux	no reaction

each correct answer gets (1)

(7 × 1)

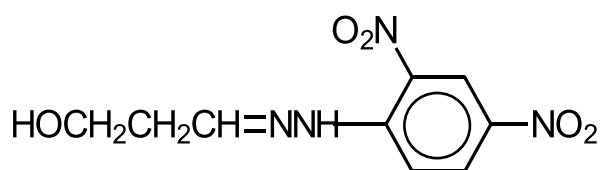
(ii)

reaction	colour at the beginning of the reaction	colour at the end of the reaction
B	blue	brick red

each correct answer gets 1

(1 + 1 + 1) [10]

(b) (i)



(1)

(ii) red or orange

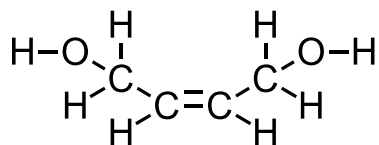
(1) [2]

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- 5 (a) (i) carboxylic acid **or** alcohol present **or** carboxylic acid **and** alcohol present **not** acid **or** carboxyl **or** hydroxyl (1)
- (ii) carboxylic acid **not** present **or** only alcohol present (1)
- (iii) alkene **or** $>C=C<$ present (1) [3]

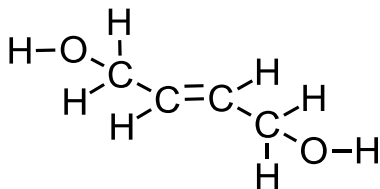
(b) (i)



each correct structure gets (1)

(4 × 1)

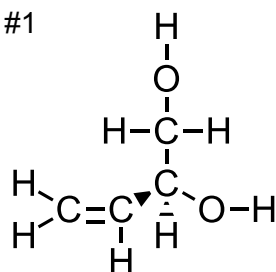
- (ii) pair 1 geometrical **or** *cis-trans* **or** *E/Z* isomerism (1)



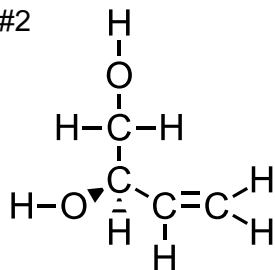
pair 2 optical isomerism – accept chiral compounds

(1) [6]

#1



#2



[Total: 9]

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1 In this question, numerical answers should be given to three significant figures.



$$1200 \text{ g C}_6\text{H}_{12}\text{O}_6 \rightarrow \frac{6 \times 200}{180} \text{ mol CO}_2$$

$$= 40.0 \text{ mol to 3 sf}$$

allow ecf on wrong equation and/or wrong M_r (1)

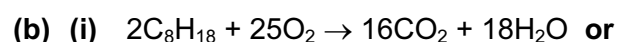


$$= 2.728 \times 10^{11} \text{ mol CO}_2$$
 (1)

$$2.728 \times 10^{11} \text{ mol CO}_2 \equiv 2.728 \times 10^{11} \times 44 = 1.20032 \times 10^{13} \text{ g}$$

$$= 1.20 \times 10^7 \text{ tonnes CO}_2 \text{ to 3 sf}$$
 (1) [5]

allow ecf on answer from **(ii)**



$$\text{mass of } 4.00 \text{ dm}^3 \text{ of octane} = 4000 \times 0.70 = 2800 \text{ g}$$
 (1)

$$n(\text{C}_8\text{H}_{18}) = \frac{2800}{114} = 24.56140351 \text{ mol in } 4.00 \text{ dm}^3$$

$$= 24.6 \text{ mol to 3 sf}$$
 (1)



$$24.6 \text{ mol C}_8\text{H}_{18} \text{ produce } \frac{16 \times 44 \times 24.6}{2} \text{ g CO}_2$$

$$= 8659.2 \text{ g CO}_2$$

$$= 8660 \text{ g CO}_2 \text{ to 3 sf}$$
 (1) [5]

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(c) 6.82×10^9 people produce 1.20×10^7 tonnes CO_2 per day

8660 g CO_2 produced when car travels 100 km

when travelling 1 km, car produces $\frac{8660}{100} = 8.66 \times 10^{-1}$ g

$= 8.66 \times 10^{-5}$ tonnes (1)

to produce 1.20×10^7 tonnes CO_2 car must travel

$$\frac{1.20 \times 10^7}{8.66 \times 10^{-5}}$$

$= 1.385681293 \times 10^{11} = 1.39 \times 10^{11}$ km to 3 sf (1) [2]

(d) possible pollutants and the damage they cause

CO	NO _x		SO ₂	H ₂ O	C	unburned C ₈ H ₁₈
	NO	NO ₂				
toxic	toxic	toxic	toxic			
	global warming	respiratory problems	respiratory problems	global warming	respiratory problems	respiratory problems
	photochemical smog	acid rain	acid rain			

compound (1)

damage (1) [2]

[Total: 14]

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- 2 (a) (i) white fumes/steamy fumes (1)
- (ii) $\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{NaHSO}_4 + \text{HCl}$ **or**
 $2\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HCl}$ (1)
- (iii) an acid that is completely ionised in solution **or**
an acid that is completely dissociated into H^+ ions in solution (1) [3]
- (b) (i) purple/violet vapour (I_2) or black/brown solid (I_2) **or**
irritating/acrid gas (SO_2) or stinking gas (H_2S) **or**
yellow solid (S) (1)
- (ii) conc. H_2SO_4 is an oxidising agent **or** HI is a reducing agent (1)
which oxidises HI **or** which reduces H_2SO_4 (1) [3]
- (c) (i) white ppt formed – **not** creamy white or off white (1)
which dissolves in $\text{NH}_3(\text{aq})$ (1)
- (ii) $\text{NaCl}(\text{aq}) + \text{AgNO}_3(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$ **or**
 $\text{Cl}^-(\text{aq}) + \text{Ag}^+(\text{aq}) \rightarrow \text{AgCl}(\text{s})$
- equation (1)
all state symbols correct (1)
- $\text{AgCl}(\text{s}) + 2\text{NH}_3(\text{aq}) \rightarrow [\text{Ag}(\text{NH}_3)_2]^+ \text{Cl}^-(\text{aq})$ **or**
 $\text{AgCl}(\text{s}) + 2\text{NH}_3(\text{aq}) \rightarrow [\text{Ag}(\text{NH}_3)_2] \text{Cl}(\text{aq})$
- equation (1)
all state symbols correct (1)
- (iii) precipitate is yellow (1)
precipitate does not dissolve (1) [8]

[Total: 14]

Page 5	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2012	9701	23

3 (a) manufacture of ammonia/Haber process **or** hydrogenation of fats/oils **or** making margarine **or** hydrocracking (1) [1]

(b) (i) **increasing the pressure**
equilibrium will move to LHS (1)
fewer moles/molecules on LHS or more moles/molecules on RHS (1)

(ii) **decreasing the temperature**
equilibrium will move to LHS (1)
forward reaction is endothermic (1) [4]

(c) rate will increase (1)
collisions will occur more frequently (1) [2]

(d) (i) $K_c = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$ (1)

(ii)

	CO(g)	+ H ₂ O(g)	⇌	CO ₂ (g)	+ H ₂ (g)
initial moles	0.40	0.40		0.20	0.20
equil moles	(0.40 – y)	(0.40 – y)		(0.20 + y)	(0.20 + y)
equil concn./mol dm ⁻³	$\frac{(0.40 - y)}{1}$	$\frac{(0.40 - y)}{1}$		$\frac{(0.20 + y)}{1}$	$\frac{(0.20 + y)}{1}$

$$K_c = \frac{(0.20 + y)^2}{(0.40 - y)^2} = 6.40 \times 10^{-1} \quad (1)$$

$$\frac{(0.20 + y)}{(0.40 - y)} = \sqrt{6.40 \times 10^{-1}} = 0.8$$

$$(0.20 + y) = 0.8 \times (0.40 - y)$$

$$0.20 + y = 0.32 - 0.8y$$

$$1.8y = 0.12$$

$$\text{gives } y = 0.067 \quad (1)$$

at equilibrium

$$\begin{aligned} n(\text{CO}) &= n(\text{H}_2\text{O}) = (0.40 - 0.067) = 0.33 \text{ mol and} \\ n(\text{CO}_2) &= n(\text{H}_2) = (0.20 + 0.067) = 0.27 \text{ mol} \end{aligned} \quad (1)$$

allow ecf as appropriate [5]

[Total: 12]

Page 6	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2012	9701	23

4 (a) (i)

reaction	organic compound	reagent	structural formulae of organic product
A	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$	NaBH_4	no reaction
B	CH_3COCH_3	Tollens' reagent warm	no reaction
C	$\text{CH}_3\text{CO}_2\text{CH}(\text{CH}_3)_2$	$\text{KOH}(\text{aq})$ warm	$\text{CH}_3\text{CO}_2\text{K}$ or CH_3CO_2^- + $(\text{CH}_3)_2\text{CHOH}$
D	$(\text{CH}_3)_3\text{COH}$	$\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ heat under reflux	no reaction
E	CH_3COCH_3	NaBH_4	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
F	$(\text{CH}_3)_3\text{COH}$	PCl_5	$(\text{CH}_3)_3\text{CCl}$
G	$\text{CH}_3\text{CH}=\text{CHCH}_2\text{OH}$	$\text{MnO}_4^-/\text{H}^+$ heat under reflux	$\text{CH}_3\text{CO}_2\text{H}$ + $\text{HO}_2\text{CCO}_2\text{H}$

each correct answer gets 1

(9 × 1)

(ii)

reaction	colour at the beginning of the reaction	colour at the end of the reaction
G	purple	colourless not clear

(1 + 1 + 1) [12]

[Total: 12]

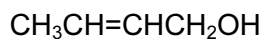
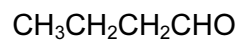
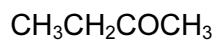
Page 7	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2012	9701	23

5 (a) (i)

H

J

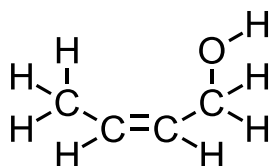
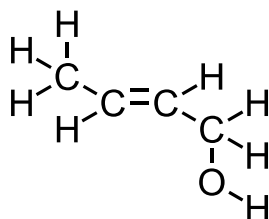
K



each correct answer gets 1

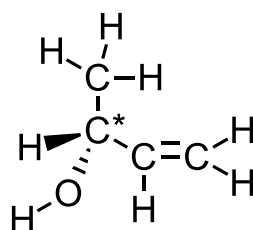
(5 x 1)

(ii)



(1)

(iii)



correct structure drawn fully displayed
chiral centre clearly shown by*

(1)

(1)

[8]

[Total: 8]