MARK SCHEME for the May/June 2011 question paper
for the guidance of teachers

9701 CHEMISTRY
9701/41 Paper 4 (A2 Structured Questions), maximum raw mark 100

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.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- Cambridge will not enter into discussions or correspondence in connection with these mark schemes.

Cambridge is publishing the mark schemes for the May/June 2011 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.
1 (a) N≡N triple bond is (very) strong
or the N₂ molecule has no polarity [1]

(b) 3Mg(s) → 3Mg²⁺(g)  \[ ΔH_1 = 3 \times 148 + 3 \times 2186 = 7002 \]
N₂(g) → 2N³⁻(g)  \[ ΔH_2 = 994 + 2 \times 2148 = 5290 \]

\[ LE = -ΔH_1 - ΔH_2 - 461 = -12,753 \text{ (kJ mol}^{-1}\text{)} \]

(c) (i) Li₃N + 3H₂O → NH₃ + 3LiOH (balanced equation) [1]

(ii) advantage: no high pressure/temperature/catalyst needed/standard conditions used [1]

disadvantage: Li is expensive
or Li would need to be recycled/removed
or LiOH by-product is corrosive/strongly basic
or this would be a batch, rather than continuous process [1]

(d) (i) Li₃N: 100 × 14/35 = 40% N [1]
urea: 100 × 28/60 = 47% N [1]

(ii) amide [1]

(iii) NH₂CONH₂ + H₂O → 2NH₃ + CO₂
or → NH₂CO₂H + NH₃
or NH₂CONH₂ + 2H₂O → 2NH₃ + H₂CO₃ [1]

(iv) The LiOH would be strongly alkaline
or would increase the pH of the soil
or would ‘burn’ the crops/reduce plant growth/stunt plants
or would contaminate the environment [1]

[Total: 12]
2 (a) (i) One that can go in either direction. [1]

(ii) both forward & reverse reactions are going on at the same time, but the concentrations of all species do not change (owtte) or rate of forward = rate of backward reaction [1]

(b) (i) $K_c = [H^+][OH^-]/[H_2O]$ [1]

(ii) $K_w = [H^+][OH^-]$ rearrangement of equation in (i) gives $K_c[H_2O] = [H^+][OH^-]$ & $K_w = K_c[H_2O]$ (owtte) or the $[H_2O]$ is contained within $K_w$ [1]

(iii) $K_w$ will be higher in hot water because reaction is endothermic [1]

(c) (i) $[OH^-] = 5 \times 10^{-2}$; $[H^+] = (1 \times 10^{-14})/ 5 \times 10^{-2} = 2 \times 10^{-13}$ pH $= -\log_{10}[H^+] = 12.7$ (correct ans = [2]) ecf [1]

(ii) $[NH_4^+] = [OH^-] = x$ $x^2 = 1.8 \times 10^{-5} \times 0.05 \Rightarrow x = 9.49 \times 10^{-4}$ (mol dm$^{-3}$) (correct ans = [2]) [1]

(iii) $[H^+] = K_w/[OH^-] = (1 \times 10^{-14})/ 9.49 \times 10^{-4} = 1.05 \times 10^{-11}$ (mol dm$^{-3}$) ecf [1]

(iv) pH $= 11.0$ ecf [1]

[Total: 12 max 11]

3 (a) (+)1; (+)2; (+)3; (+)4 O.N. corresponds to the no. of electrons in outer/valence shell/lost [1]

(b) PC$_5$ fizzes or white/misty fumes or heat evolved

PC$_5$ + 4H$_2$O $\rightarrow$ H$_3$PO$_4$ + 5HCl or PC$_5$ + 3H$_2$O $\rightarrow$ HPO$_3$ + 5HCl (allow partial hydrolysis: PC$_5$ + H$_2$O $\rightarrow$ POC$_3$ + 2HCl) [1]

(c) (i) $P = 30.4/31 = 0.98 \quad Cl = 69.6/35.5 = 1.96$ Thus E.F. = PC$_2$

$M_r($PC$_5$) = 102, so 2 $\times$ PC$_5$ = 204 $\approx$ 200, so M.F. = $P_2Cl_4$ [1]

(ii) (ignore lone pairs on Cl) [1]

(iii) O.N. = (+)2 [1]

(iv) (HO)$_2$P-P(OH)$_2$ or H(HO)P(=O)-P(=O)(OH)H ecf from structure in (ii) [1] Allow HO-P-OH or HO-P=O [1]

[Total: 10]
4 (a) \( N_2 + 2O_2 \rightarrow 2NO_2 \) (or via NO) or \( 2NO + O_2 \rightarrow 2NO_2 \)  

(b) (i) catalytic converter and passing the exhaust gases over a catalyst/Pt/Rh  
(ii) \( NO_2 + 2CO \rightarrow \frac{1}{2} N_2 + 2CO_2 \) or similar  
Allow \( 2NO_2 + CH_4 \rightarrow CO_2 + N_2 + 2H_2O \)  

(c) No, it wouldn’t be reduced. Because the reaction in (a) does not presuppose a particular fuel (owtte)  
Allow formed from \( N_2 \) and \( O_2 \) in air during combustion  

(d) (i) \( SO_3 \) produces acid rain  
(ii) \( NO + \frac{1}{2} O_2 \rightarrow NO_2 \)  
(iii) \( K_p = \frac{(p_{NO} \cdot p_{SO_2})}{(p_{NO_2} \cdot p_{SO_2})} \)  
units: dimensionless/none (don’t accept just a blank!)  
(iv) \( K_p = 99.8^2/0.2^2 = 2.5 \times 10^5 \)  
(v) It will shift to the right (owtte) because the reaction is exothermic. NOT just Le Chatelier argument  

[Total: 11]

5 (a) 

<table>
<thead>
<tr>
<th>transformation</th>
<th>reagent + conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_2H_4 \rightarrow C_2H_5Cl )</td>
<td>HCl, no light or catalyst</td>
</tr>
<tr>
<td>( C_2H_5OH \rightarrow C_2H_5Cl )</td>
<td>conc HCl + ZnCl₂ or SOCl₂ or PCl₅ or PCl₃ and heat</td>
</tr>
<tr>
<td>( C_2H_6 \rightarrow C_2H_5Cl )</td>
<td>Cl₂ + light</td>
</tr>
<tr>
<td>( C_2H_4 \rightarrow C_2H_5Cl )</td>
<td>Cl₂, no light or catalyst</td>
</tr>
<tr>
<td>( CH_3CO_2H \rightarrow CH_3COCl )</td>
<td>SOCl₂ or PCl₅ or PCl₃ and heat</td>
</tr>
<tr>
<td>( \text{H}<em>3\text{C}\text{C}</em>\text{H}_3 \rightarrow \text{H}<em>3\text{C}\text{C}</em>\text{H}_3\text{Cl} )</td>
<td>Cl₂ + AlCl₃</td>
</tr>
<tr>
<td>( \text{C}_\text{H}<em>3\text{C}</em>\text{H}<em>3 \rightarrow \text{C}</em>\text{H}<em>3\text{C}</em>\text{H}_3\text{Cl} )</td>
<td>Cl₂ + light or heat</td>
</tr>
</tbody>
</table>

[6]
(b) (i) production of NO₂⁺: 2H₂SO₄ + HNO₃ → 2HSO₄⁻ + H₃O⁺ + NO₂⁺  
(accept H₂SO₄ + HNO₃ → HSO₄⁻ + H₂O + NO₂⁺)

![Chemical structure diagram]

curly arrow from ring to NO₂⁺ and from C-H bond to ring  
correct intermediate, including charge in the right place  
*Note charge area must be more than half ring*  

(ii) C is C₆H₅CO₂H  

(iii) step 1: reagent is hot acidified or alkaline KMnO₄  
step 2: reagent is Br₂ + FeBr₃/AlCl₃ etc. (H₂O or light negates)  

(If C is given as 3-bromotoluene, then allow the last [2] marks if steps 1 and 2 are reversed.)

[Total: 12]

6 (a) (i) aqueous alkaline iodine *or* I₂ + OH⁻(aq)  
allow NaClO + KI  

(ii) CH₃CO⁻ *or* CH₃CH(OH)-  

(iii) Pale yellow ppt. *or* antiseptic smell  

(iv)

<table>
<thead>
<tr>
<th>compound</th>
<th>result</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃OH</td>
<td>×</td>
</tr>
<tr>
<td>CH₃CH₂OH</td>
<td>✓</td>
</tr>
<tr>
<td>CH₃CHO</td>
<td>✓</td>
</tr>
<tr>
<td>CH₃CO₂H</td>
<td>×</td>
</tr>
<tr>
<td>![Chemical structure]</td>
<td>×</td>
</tr>
<tr>
<td>![Chemical structure]</td>
<td>✓</td>
</tr>
</tbody>
</table>

[3]
(b) (allow displayed, skeletal or structural formulae)

\[
\text{CHO} + \text{CO}_2\text{H} \rightarrow \text{E}
\]

for D allow

\[
\text{CHO}
\]

(D + E + F): 3 [1]

(c) (allow displayed, skeletal and structural formulae)

Must be consistent with F

\[
\text{G} \quad \text{H} \quad \text{J} \quad \text{K}
\]

allow for G if G is the 3-OH acid

(N.B. letters H, J, K can be swapped around)

(G + H + J + K): 4 [1]

geometrical or cis-trans isomerism

[Total: 14]
7  (a) The tertiary/3-dimensional structure/shape is held together by hydrogen/ionic/van der Waals bonds [1]
These break relatively easily/are weak/break at/above 45 °C [1]

(b) (or similar diagrams)

Enzyme + substrate     Enzyme-substrate complex     Enzyme + products  3 × [1]

(c) a competitive inhibitor combines with the enzyme’s active site (so preventing the substrate from binding) [1]
non-competitive inhibitor bonds with the enzyme away from the active site/at an allosteric site [1]
this changes the shape of the active site [1]

Also allow competitive inhibition can be overcome by increasing [substrate] or non-competitive inhibition cannot be removed by increasing [substrate] for the 3rd mark

(d) (i)

Line must be of similar shape to original but level out below original line [1]

(ii) Inhibitor reduces the number of enzymes with ‘working’ active sites (owtte) [1]

[Total: 10]
8 (a) **partition** – separation due to the different solubilities of compounds in two solvents/ phases [1]

**adsorption** – separation due to the different attractions between the compounds and the stationary phase, relative to their solubility in the solvent [1]

Note, if candidates do not refer to different solubilities and different attractions max 1

(b)

Ring: [1]

A + B: [1]

(c) (i) X is bromine – M and (M+2) peaks almost same height [1]

(ii) \[ \frac{M}{M+1} = \frac{100 \times 9}{1.1 \times n} = \frac{100}{0.3} \quad 1.1 \times n \]

Hence \[ n = \frac{100 \times 0.3}{1.1 \times 9} = 3.03 \quad p = 3 \]

(answer + working) [1]

(If the mass peak is at 122 and the compound contains Br and 3 C atoms then \( Q = (122 - 79 - 36) \)) thus \( Q = 7 \) ecf from (ii) [1]

(The compound is \( C_3H_7Br \))

(iii) \( (R \text{ is at } m/e 43) \), hence \( C_3H_7^+ \) [1]

(d) Any two from \( H_2, \ H_2O, \ CO, \ C_2H_4, \ C_2H_2, \ CH_4 \) \( 2 \times [1] \)

[Total: 10]
9  (a)  (i) One [1]  

dii) Any alkene (or allow a cyclic amide, as in caprolactam) [1] 

(b) Any TWO from: addition needs unsaturated/double bonds/alkene 
condensation eliminates a small molecule 
condensation needs a molecule other than a hydrocarbon 
empirical formula of addition polymer is the same as that of its monomer 
condensation needs two different functional groups  

(NOT – “condensation needs two different monomers”)  2 × [1] 

(c)  (i) Water [1]  
	(ii) \[
\begin{align*}
&\text{Correct ‘ester’ bond} \\
&\text{‘sticks’ to rest of molecule}  \\
&\text{Note: candidates need only show ‘brackets’ if more than one repeat unit shown}  \\
&\text{(iii) Polyesters} [1]
\end{align*}
\]

(d) Monomers in Terylene have to alternate in order to condense out water (owtte) [1] 

Alkenes can link in any order (and still form a polyalkene) (or diagram showing this) [1]  

[Total: 10]