CAMBRIDGE INTERNATIONAL EXAMINATIONS
GCE Advanced Level

MARK SCHEME for the October/November 2012 series

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 should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge will not enter into discussions about these mark schemes.

Cambridge is publishing the mark schemes for the October/November 2012 series for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level components and some Ordinary Level components.
1 (a) SiCl₄: **white** solid or **white/steamy** fumes [1]

\[
\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl} \\
\]

PCl₅: fizzes or **white/steamy** fumes [1]

\[
\text{PCl}_5 + 4\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + 5\text{HCl}\]

(b) (i) \(\text{MnO}_4^- + 8\text{H}^+ + 5\text{Fe}^{2+} \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O} + 5\text{Fe}^{3+}\) [1]

(ii) 5 : 1

(iii) \(n(\text{MnO}_4^-) = 0.02 \times 15/1000 = 3 \times 10^{-4}\) (mol) [1]

(iv) \(n(\text{Fe}^{2+}) = 5 \times 3 \times 10^{-4} = 1.5 \times 10^{-3}\) (mol) ecf from (i) or (ii) [1]

(v) \([\text{Fe}^{2+}] = 1.5 \times 10^{-3} \times 1000/2.5 = 0.6\) (mol dm\(^{-3}\)) ecf from (iv) [1]

(vi) In the original solution, there was 0.15 mol of \(\text{Fe}^{3+}\) in 100 cm\(^3\). In the partially-used solution, there is 0.06 mol of \(\text{Fe}^{2+}\) in 100 cm\(^3\).

So remaining \(\text{Fe}^{3+} = 0.15 - 0.06 = 0.09\) mol. ecf from (v) [1]

This can react with 0.045 mol of Cu, which = 0.045 \times 63.5 = **2.86 g** of copper. ecf [1]

(c) bonds broken are Si-Si and Cl-Cl = 222 + 244 = 466 kJ mol\(^{-1}\)
bonds formed are 2 \times Si-Cl = 2 \times 359 = 718 kJ mol\(^{-1}\)
\[\Delta H = -252\text{ kJ mol}^{-1}\] [2]

(d) (i) \(\text{Ca}_2\text{Si} + 6\text{H}_2\text{O} \rightarrow 2\text{Ca(OH)}_2 + \text{SiO}_2 + 4\text{H}_2\) [1]

(ii) silicon has been oxidised **AND** hydrogen has been reduced [1]

[Total: 14]
2 (a) (i) \( A = \text{CuSO}_4 \)
\( B = \text{silver} \)  

(ii) salt bridge
voltmeter

(b) (i) 0.80 – 0.34 = (+) 0.46 V  

(ii) If \( E_{\text{cell}} = 0.17 \), this is 0.29 V less than the standard \( E^\circ \), so \( E_{\text{Ag electrode}} \) must = 0.80 – 0.29 = 0.51 V  

(iii) 0.51 = 0.80 + 0.06log [Ag\(^+\)], so [Ag\(^+\)] = \( 10^{(-0.29/0.06)} = 1.47 \times 10^{-5} \) mol dm\(^{-3} \) ecf from (ii)

(c) (i) \( K_{\text{sp}} = [\text{Ag}^+]^2[\text{SO}_4^{2-}] \)  
units = mol\(^3\) dm\(^{-9}\) ecf on \( K_{\text{sp}} \)

(ii) [SO\(_4^{2-}\)] = [Ag\(^+\)]/2  \( K_{\text{sp}} = (1.6 \times 10^{-2})^2 \times 0.8 \times 10^{-2} = 2.05 \times 10^{-8} \) (mol\(^3\) dm\(^{-9}\))

(d) AgCl white
AgBr cream
AgI yellow

Solubility decreases down the group

(e) solubility decreases down the group  
as \( M^{2+}/\text{ionic} \) radius increases  
both lattice energy and hydration(solvation) energy to decrease  
enthalpy change of solution becomes more endothermic

[Total: 18]
3 (a) (i) heterogeneous: different states AND homogeneous: same state  

(ii) the correct allocation of the terms heterogeneous and homogeneous to common catalysts  

example of heterogeneous, e.g. Fe (in the Haber process) linked to correct system  

\[
N_2 + 3H_2 \rightarrow 2NH_3
\]  

how catalyst works, adsorption (onto the surface)  

ecf for non-iron catalyst  

example of homogeneous, e.g. Fe\(^{3+}\) or Fe\(^{2+}\) (in \(S_2O_8^{2-}\) + I\(^{-}\)) linked to correct system  

\[
S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2
\]  

how catalyst works, e.g. Fe\(^{3+}\) + I\(^{-}\) \(\rightarrow\) Fe\(^{2+}\) + \(\frac{1}{2}\)I\(_2\)  

ecf for non-iron catalyst  

(b)  

both \(E_a\) shown, with \(E_a(1) > E_a(2)\)  

both \(\Delta H\) shown, with \(\Delta H(1) > \Delta H(2)\)  

[2]

[Total: 10]
4  (a)  $K_2Cr_2O_7 + H^+ + \text{heat under reflux}$  [1]

(b) nucleophilic substitution  [1]

(c) heat under reflux + aqueous HCl  [1]

(d) alkene  [1]

(e) amide or ester  [1]

(f) alternative structure for capsaicin  [5]

[Total: 10]
5 (a) phenol
ketone

(b)

<table>
<thead>
<tr>
<th>reagent</th>
<th>observation</th>
<th>structure of product</th>
<th>type of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>sodium metal</td>
<td>effervescence/bubbles/fizzing</td>
<td>[structure of product]</td>
<td>redox</td>
</tr>
<tr>
<td>aqueous bromine</td>
<td>decolourises or white ppt.</td>
<td>[structure of product]</td>
<td>electrophilic substitution</td>
</tr>
<tr>
<td>aqueous alkaline iodine</td>
<td>yellow ppt.</td>
<td>[structure of product]</td>
<td>oxidation</td>
</tr>
</tbody>
</table>

(c) (i)

\[
\begin{align*}
\text{J} & : & \text{N}_2\text{SO}_3\text{H} \\
\text{K} & : & \text{N}_2^+\text{SO}_3\text{H}
\end{align*}
\]

[1] + [1]
(ii) step 1: NaNO₂ + HCl or HNO₂

at T < 10°C

step 2: (add K to a solution of G) in aqueous NaOH

(d) \( \text{SOCl}_2/\text{PCl}_5 \) /PCl₃ + heat \( \rightarrow \) add to G (in NaOH(aq))

\( \text{CH₃CH₂CO₂H} \rightarrow \text{CH₃CH₂COCl} \rightarrow \text{L} \)

ecf from CH₃COOH

[Total: 18]
Section B

6 (a) bonding | structure involved
--- | ---
disulfide bonds between parts of the chain | tertiary
hydrogen bonds in a β-pleated sheet | secondary
ionic bonds between parts of the chain | tertiary
peptide links between amino acids | primary

zero/one correct only → [0], two correct only → [1], three correct only → [2] all four correct [3]

(b) labelled diagrams such as:

Competitive *any two from*:
- complementary shape to substrate / able to bind to active site of enzyme
- so preventing the substrate from binding / able to compete with substrate
- can be overcome by increasing [substrate] 2 × [1]

Non-competitive: *any two from*:
- binds elsewhere in the enzyme than active site / at an allosteric site
- this changes the shape of the active site
- cannot be removed by increasing [substrate] 2 × [1]
7 (a) (i) Electrophoresis [1]
(ii) Using a restriction enzyme. [1]
(iii) The phosphate group. [1]

(b) (i) X labelled correctly on diagram. [1]
(ii) Suspect 2 AND matches crime scene 1 or matches at least one crime scene. [1]
(c) P is CH₃CO₂CH₂CH₃

any four of:
- 3 different (proton) environments
- (M and M+1 data shows no of carbons present is) \( (100 \times 0.22)/(1.1 \times 5.1) = 4 \text{ carbons} \)
- the NMR spectrum shows 8 hydrogens leaving 32 mass unit or 2 oxygen or
  \( M_r = 88 \) and (molecular formula is) \( C_4H_8O_2 \)
- 4 peaks/quartet (at 4.1) shows an adjacent 3H/CH₃
- 3 peaks/triplet (at 1.3) shows an adjacent 2H/CH₂
- (peak at) 2.0/singlet shows CH₃CO (group)
- (peak at) 4.1/quartet and 1.3/triplet shows presence of ethyl/CH₃CH₂ (group)

\[ 4 \times [1] \]

[Total: 10]

8 (a) (i) It could denature the enzyme or
alter the 3D structure/tertiary structure/shape of active site. [1]

(ii) condensation [1]

(b)

or correct diagram of the S isomer [1]

(c) (i) (Acid present would) hydrolyse the ester (linkage) [1]

(ii) (Hot water would) soften (the container) [1]
(d) (i) 

\[
\begin{array}{c}
\text{H} & \text{O} & \text{CH}_3 & \text{O} \\
\text{O} & \text{C} & \text{O} & \text{C} & \text{C} \\
\text{H} & \text{H} & \text{H} & & \\
\end{array}
\]

ester linkage shown \[1\]
rest of repeat unit correct (ONE) \[1\]

(ii) van der Waals’ from CH₃/methyl group \[1\]
permanent dipole-dipole from ester group \[1\]

(iii) Accept any sensible physical property suggestion e.g. different melting point or different density or different solubility. \[1\]

[Total: 10]