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.

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 October/November 2011 question papers for most
IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level
syllabuses.
1 (a) (i) mass of C = \( \frac{12 \times 0.352}{44} \) = 0.096g (1)

\[ n(C) = \frac{0.096}{12} = 0.008 \] (1)

(ii) mass of H = \( \frac{2 \times 0.144}{18} \) = 0.016g (1)

\[ n(H) = \frac{0.016}{1} = 0.016 \] (1)

(iii) mass of oxygen = 0.240 – (0.096 + 0.016) = 0.128g (1)

\[ n(O) = \frac{0.128}{16} = 0.008 \] (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 C\(_2\)H\(_2\)O (1) [1]

(c) (i) \( M_e = \frac{mRT}{pV} = \frac{0.148 \times 8.31 \times 333}{1.01 \times 10^5 \times 67.7 \times 10^{-6}} \) (1)

= 59.89

allow 59.9 or 60 (1)

(ii) C\(_2\)H\(_4\)O\(_2\) (1) [3]

(d) CH\(_3\)CO\(_2\)H (1)

HCO\(_2\)CH\(_3\) (1) [2]

(e) the only products of the reaction are the two oxides H\(_2\)O and CO\(_2\) and copper (1) [1]

[Total: 13]
2 (a) \[ S(g) \rightarrow S^+(g) + e^- \]
   correct equation \hspace{1cm} (1)
   correct state symbols \hspace{1cm} (1) \hspace{0.5cm} [2]

(b) from Na to Ar,
   electrons are added to the same shell/have same shielding \hspace{1cm} (1)
   electrons are subject to increasing nuclear charge/proton number \hspace{1cm} (1)
   electrons are closer to the nucleus or atom gets smaller \hspace{1cm} (1) \hspace{0.5cm} [3]

(c) (i) Mg and Al
   in Mg outermost electron is in 3s and \hspace{1cm} (1)
   in Al outermost electron is in 3p
   3p electron is at higher energy or \hspace{1cm} (1)
   is further away from the nucleus or
   is more shielded from the nucleus

(ii) S and P
   for S one 3p orbital has paired electrons and \hspace{1cm} (1)
   for P 3p sub-shell is singly filled
   paired electrons repel \hspace{1cm} (1) \hspace{0.5cm} [4]

(d) (i) and (ii)

<table>
<thead>
<tr>
<th>element</th>
<th>Na</th>
<th>Mg</th>
<th>Al</th>
<th>Si</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>conductivity</td>
<td>high</td>
<td>high</td>
<td>—</td>
<td>moderate</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>melting point</td>
<td>low</td>
<td>high</td>
<td>—</td>
<td>high</td>
<td>low</td>
<td>low</td>
</tr>
</tbody>
</table>

   (1) \hspace{1cm} (1) \hspace{1cm} (1) \hspace{1cm} (1) \hspace{1cm} (1) \hspace{1cm} [5]

(e) germanium/Ge \hspace{1cm} (1) \hspace{1cm} [1]

[Total: 15]
3 (a) the overall enthalpy change/energy change/\(\Delta H\) for a reaction is independent of the route taken or is independent of the number of steps involved provided the initial and final conditions are the same \(\text{(1)}\) \(\text{[2]}\)

(b) (i) \(\text{K}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{KCl} + \text{H}_2\text{O} + \text{CO}_2\) \(\text{(1)}\)

(ii) heat produced = m \times c \times \delta T = 30.0 \times 4.18 \times 5.2
\(= 652.08\ \text{J per 0.0200 mol of K}_2\text{CO}_3\) \(\text{(1)}\)

(iii) 0.020 mol \(\text{K}_2\text{CO}_3 \equiv 652.08\ \text{J}\)
\(1\ \text{mol K}_2\text{CO}_3 \equiv \frac{652.08 \times 1}{0.0200} = 32604\ \text{J}\)
enthalpy change = \(-32.60\ \text{kJmol}^{-1}\) \(\text{(1)}\)

(iv) to prevent the formation of \(\text{KHCO}_3\) or to ensure complete neutralisation \(\text{(1)}\) \(\text{[4]}\)

(c) (i) \(\text{KHCO}_3 + \text{HCl} \rightarrow \text{KCl} + \text{H}_2\text{O} + \text{CO}_2\) \(\text{(1)}\)

(ii) heat absorbed = m \times c \times \delta T = 30.0 \times 4.18 \times 3.7
\(= 463.98\ \text{J per 0.0200 mol of KHCO}_3\) \(\text{(1)}\)

(iii) 0.020 mol \(\text{KHCO}_3 \equiv 463.98\ \text{J}\)
\(1\ \text{mol KHCO}_3 \equiv \frac{463.98 \times 1}{0.0200} = 23199\ \text{J}\)
enthalpy change = \(+23.20\ \text{kJmol}^{-1}\) \(\text{(1)}\) \(\text{[3]}\)

(d) \(\Delta H = 2 \times (+23.20) - (-32.60) = +79.00\ \text{kJ mol}^{-1}\) \(\text{(2)}\) \(\text{[2]}\)

[Total: 11]
4 (a)

\[
\begin{array}{c}
\text{CH}_3\text{CH}_2\text{CH} = \text{CH}_2 \\
\text{H}_2\text{O}(g) \quad \text{H}_3\text{PO}_4 \\
\text{catalyst} \\
\text{MnO}_4^-/\text{H}^+ \\
\text{hot, concentrated} \\
\end{array}
\]

\[
\begin{array}{c}
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \\
\text{or} \\
\text{CH}_3\text{CH}_2\text{CH(OH)CH}_3 \\
\text{T} \\
\text{CH}_3\text{CH}_2\text{CH(OH)CH}_2\text{OH} \\
\text{V} \\
\text{Cr}_2\text{O}_7^{2-}/\text{H}^+ \\
\text{heat under reflux} \\
\text{CH}_3\text{CH}_2\text{COCO}_2\text{H} \\
\text{W} \\
\end{array}
\]

- correct T (1)
- correct U (1)
- correct V (1)
- correct > CO group in W (1)
- correct –CO_2H group in W (1) [5]
(b) T + U

\[
\begin{align*}
&\text{H} - \text{C} - \text{C} - \text{O} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \\
&\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
&\text{H} \quad \text{H} \\
\end{align*}
\]

or

\[
\begin{align*}
&\text{H} - \text{C} - \text{C} - \text{O} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \\
&\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
&\text{H} \quad \text{H} \\
\end{align*}
\]

correct structures

correctly displayed ester group

(1) [2]

[Total: 7]

5 (a) (i) 1 primary alcohol not hydroxyl

2 aldehyde not carbonyl

(ii)

<table>
<thead>
<tr>
<th>Test 1</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reagent</td>
<td>Na</td>
<td>PCl3/PCl5/PBr3</td>
<td>RCO2H/H+</td>
</tr>
<tr>
<td>Observation</td>
<td>gas/H2/effervescence/fizzing</td>
<td>HC1/HBr/steamy fumes</td>
<td>fruity smell</td>
</tr>
</tbody>
</table>

| Test 2 | | | |
|---|---|---|
| Reagent | Tollens’ reagent | Fehling’s reagent | 2,4-dinitrophenylhydrazine |
| 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]
(b) (i) \[ \text{HOCH}_2\text{CHO} \]

(ii) \[ \text{HOOCCH(OH)COOH} \]

5 (c)

<table>
<thead>
<tr>
<th>route</th>
<th>starting compound</th>
<th>first reagent</th>
<th>intermediate X</th>
<th>second reagent</th>
<th>intermediate Y</th>
<th>third reagent</th>
<th>final compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/1 HOCH_2CHO</td>
<td>PCl_3, PCl_5, SOCl_2, etc.</td>
<td>C_3H_2CHO</td>
<td>K_2Cr_2O_7/H^+\ K_2Cr_2O_7/H^+\ K_2Cr_2O_7/\text{OH}^-\ Tollens' or Fehling's reagents</td>
<td>C_3H_2CO_2H</td>
<td>NH_3</td>
<td>H\textsubscript{2}NCH_2CO_2H</td>
<td></td>
</tr>
<tr>
<td>A/2 HOCH_2CHO</td>
<td>HBr, P/Br_2 etc.</td>
<td>Br_2CH_2CHO</td>
<td>K_2Cr_2O_7/H^+\ K_2Cr_2O_7/H^+\ K_2Cr_2O_7/\text{OH}^-\ Tollens' or Fehling's reagents</td>
<td>Br_2CH_2CO_2H</td>
<td>NH_3</td>
<td>H\textsubscript{2}NCH_2CO_2H</td>
<td></td>
</tr>
<tr>
<td>B/1 HOCH_2CHO</td>
<td>PCl_3, PCl_5, SOCl_2, etc.</td>
<td>C_3H_2CHO</td>
<td>NH_3</td>
<td>H_2NCH_2CHO</td>
<td>K_2Cr_2O_7/H^+\ K_2Cr_2O_7/H^+\ K_2Cr_2O_7/\text{OH}^-\ Tollens' or Fehling's reagents</td>
<td>H\textsubscript{2}NCH_2CO_2H</td>
<td></td>
</tr>
<tr>
<td>B/2 HOCH_2CHO</td>
<td>HBr, P/Br_2 etc.</td>
<td>Br_2CH_2CHO</td>
<td>NH_3</td>
<td>H_2NCH_2CHO</td>
<td>K_2Cr_2O_7/H^+\ K_2Cr_2O_7/H^+\ K_2Cr_2O_7/\text{OH}^-\ Tollens' or Fehling's reagents</td>
<td>H\textsubscript{2}NCH_2CO_2H</td>
<td></td>
</tr>
<tr>
<td>C HOCH_2CHO</td>
<td>Tollens' or Fehling's reagents</td>
<td>HOCH_2CO_2H</td>
<td>KBr/conc. H\textsubscript{2}SO_4</td>
<td>Br_2CH_2CO_2H</td>
<td>NH_3</td>
<td>H\textsubscript{2}NCH_2CO_2H</td>
<td></td>
</tr>
</tbody>
</table>

mark \[ (1) \quad (1) \quad (1) \quad (1) \quad (1) \]

[Total: 14]