

**UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS**

**GCE Advanced Subsidiary Level and GCE Advanced Level**

## **MARK SCHEME for the October/November 2007 question paper**

### **9701 CHEMISTRY**

**9701/04**

Paper 4 (Theory 2), 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.

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Page 2	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

- 1 (a) (i)  $K_a = \frac{[H^+][RCO_2^-]}{[RCO_2H]}$  [1]
- (ii)  $pK_a = -\log_{10}K_a$  or  $-\log K_a$  or  $\log \frac{[H^+]^2}{[RCO_2H]}$  NOT  $\ln$ ; [1]  
[2]
- (b) (i) acid strength increases from no. 1 to no. 3 or down the table or as Cls increase due to the electron-withdrawing effect/electronegativity of chlorine (atoms) stabilising the anion or weakening the O-H bond NOT  $H^+$  more available [1]  
[1]  
[1]
- (ii) chlorine atom is further away (from O-H) in no. 4, so has less influence [1]
- (iii) either:  $pH = \frac{1}{2}(pK_a - \log_{10}[\text{acid}])$  or  $K_a = 10^{-pK_a} = 1.259 \times 10^{-3}$   
 $= \frac{1}{2}(4.9 + 2)$   $[H^+] = \sqrt{K_a \cdot c} = 3.55 \times 10^{-4}$  [1]  
 $= 3.4$  (allow 3.5)  $pH = 3.4$  ecf [1]  
 ([1] for correct expression & values; [1] for correct working)  
 [6]
- (c) (i) catalyst [1]
- (ii)  $CH_3CH_2CO_2H + Cl_2 \longrightarrow CH_2CHClCO_2H + HCl$  [1]
- (iii) nucleophilic substitution NOT addition/elimination [1]
- (iv)  $M_r(CH_3CH_2CO_2H) = 74$   $M_r(CH_2CH(NH_2)CO_2H) = 89$  [1]  
 $\therefore 10.0 \text{ g should give } 10 \times 89/74 = 12.03 \text{ g}$   
 $\therefore \text{percentage yield} = 100 \times 9.5/12.03 = 79\%$  ecf [1]  
 ([2] for correct answer)  
 [5]
- (d)  $^+NH_3-CH(CH_3)-CO_2^-$  correct atoms [1]  
 Allow charges on H of  $H_3N$ , and  $-COO$  but not  $-C-O-O$  correct charges [1]  
 [2]

[Total: 15]

Page 3	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

- 2 (a) solubility **decreases** (down Group II) [1]  
 lattice energy decreases [1]  
 solvation/hydration energy (of cation) decreases [1]  
 but more so than does lattice energy/is not able to overcome LE [1]  
 $\Delta H_{\text{soln}}$  becomes more endothermic/positive/less exothermic [1]  
**[max 4]**
- (b) identities of **A** and **B** 2 x [1]  
 $\text{Mg(OH)}_2 + \text{H}_2\text{C}_2\text{O}_4 \longrightarrow \text{MgC}_2\text{O}_4(\text{aq}) + 2\text{H}_2\text{O}$  [1]  
**(A)**
- $\text{MgC}_2\text{O}_4(\text{aq}) + \text{Ca(NO}_3)_2 \longrightarrow \text{Mg(NO}_3)_2 + \text{CaC}_2\text{O}_4(\text{s})$  [1]  
**(B)**  
**[max 3]**
- (c) (i) ( $K_{\text{sp}} =$ )  $[\text{Mg}^{2+}][\text{OH}^-]^2$  [1]  
 units are  $\text{mol}^3\text{dm}^{-9}$  ecf from  $K_{\text{sp}}$  [1]
- (ii) (call  $[\text{Mg(OH)}_2(\text{aq})] = [\text{Mg}^{2+}] = x$ )  $\therefore K_{\text{sp}} = 2 \times 10^{-11} = 4x^3$  [1]  
 $\therefore x = 1.71 \times 10^{-4} \text{ mol dm}^{-3}$  ecf [1]
- (iii) less soluble because of the common ion effect [1]  
 or the equilibrium  $\text{Mg(OH)}_2(\text{s}) \rightleftharpoons \text{Mg}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$  is moved to the left [1]  
**[5]**  
**[Total: 12]**

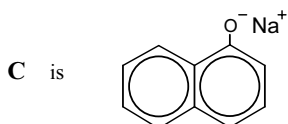


Page 5	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

- 4 (a)  $\text{CCl}_4$  is unreactive. (The rest react (with increasing vigour)) [1]  
 no d-orbitals *or* available/low-lying empty orbitals in carbon *or* unable to expand octet [1]  
 e.g.  $\text{SiCl}_4 + 2\text{H}_2\text{O} \longrightarrow \text{SiO}_2 + 4\text{HCl}$   
 (or  $\text{GeCl}_4$  etc) *or*  $\text{Si(OH)}_2\text{Cl}_2$   
*or*  $\text{Si(OH)}_4$   
 (allow balanced equations for partial hydrolysis) [1]  
**[3]**
- (b) (i)  $E(\text{C}-\text{Cl}) = 244 \text{ kJ mol}^{-1}$ ;  $2 E(\text{C}-\text{Cl}) = 2 \times 340 = 680 \text{ kJ mol}^{-1}$   
 $\therefore \Delta H = -436 \text{ (kJ mol}^{-1}\text{)}$  [1]
- (ii)  $\Delta H = 359 - 329 = +30 \text{ (kJ mol}^{-1}\text{)}$  [1]
- (iii) since reaction (ii) is endothermic, the +4 oxidation state is less stable  
*or* the +2 oxidation state is more stable (down the group) [1]  
**[3]**  
**[Total: 6]**
- 5 (a)  $2 \text{MnO}_4^- + 5 \text{H}_2\text{O}_2 + 6 \text{H}^+ \longrightarrow 2 \text{Mn}^{2+} + 8 \text{H}_2\text{O} + 5 \text{O}_2$  [1]  
**[1]**
- (b)  $E_{\text{cell}}^\ominus = 1.52 - 0.68 = +0.84 \text{ (V)}$  [1]  
**[1]**
- (c) (i) (as  $\text{KMnO}_4$  is added), colour changed (from purple) to colourless – *NOT* pink [1]  
*or* effervescence/bubbles (of  $\text{O}_2$ ) are produced [1]  
 at end-point, change is to (first) pink [1]
- (ii)  $n(\text{MnO}_4^-) = 0.02 \times 15/1000 = 3 \times 10^{-4}$  [1]  
 since  $\text{H}_2\text{O}_2 : \text{MnO}_4^- = 5:2$ ,  
 $\Rightarrow n(\text{H}_2\text{O}_2) = (5/2) \times 3 \times 10^{-4} = 7.5 \times 10^{-4} \text{ in } 25 \text{ cm}^3$   
 $\therefore [\text{H}_2\text{O}_2] = 7.5 \times 10^{-4} \times 1000/25 = 3.0 \times 10^{-2} \text{ mol dm}^{-3}$  [1]  
**[4]**  
**[Total: 6]**

Page 6	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

6 (a) (i)



allow ONa but no covalent O-Na bond

[1]

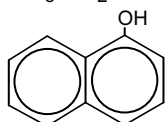
(ii) amide, ester

2 x [1]

(iii)  $\text{CO}_2$  or  $\text{H}_2\text{CO}_3$  or  $\text{Na}_2\text{CO}_3$   
 $\text{CH}_3\text{NH}_2$  or  $\text{CH}_3\text{NH}_3^+\text{Cl}^-$

[1]

[1]



[1]

(iv)  $\text{H}_3\text{O}^+$  and heat  $>80^\circ$  or  $\text{OH}^-(\text{aq})$  and heat  $>80^\circ$

[1]

[7]

(b) (i)  $\text{Br}_2(\text{aq})$  (or other suitable solvent)

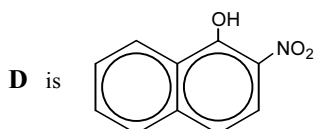
[1]

(ii) dilute/aqueous  $\text{HNO}_3$

[1]

[2]

(c) (i)

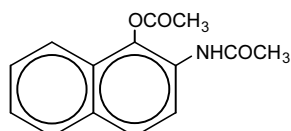


[1]

(ii) tin/Fe + HCl NOT  $\text{LiAlH}_4$

[1]

(iii)

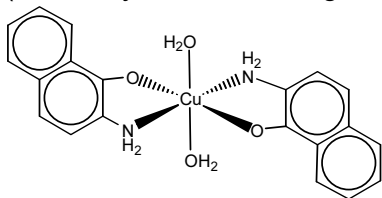


mark each side chain separately

2 x [1]

[4]

(d) (i) (allow any orientation of groups)



penalise missing H on  $\text{NH}_2$

[1]

(ii)  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  or  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$  NOT  $[\text{Cu}(\text{NH}_3)_6]^{2+}$

[1]

(iii) ligand substitution/exchange

[1]

[3]

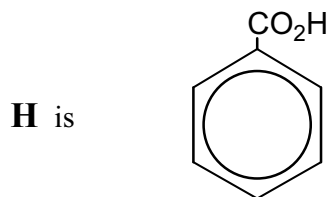
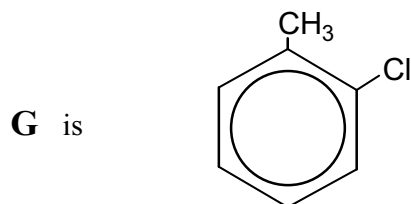
[Total: max 15]

Page 7	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

- 7 (a)  $\text{HNO}_3 + \text{H}_2\text{SO}_4$  [1]  
 at  $50 - 60^\circ\text{C}$  (or  $\leq 60^\circ\text{C}$ ) not dilute or (aq) [1]  
 [2]

- (b)  $2\text{H}_2\text{SO}_4 + \text{HNO}_3 \longrightarrow 2\text{HSO}_4^- + \text{H}_3\text{O}^+ + \text{NO}_2^+$  [1]  
 (allow equ. with only one  $\text{H}_2\text{SO}_4$ , giving  $\text{H}_2\text{O}$ ) [1]

(c)



[1] + [1]

- reaction I:  $\text{Cl}_2 + \text{AlCl}_3$ /accept other halogen carriers *NOT* aq, *nor* u.v.  
 reaction II:  $\text{KMnO}_4 + \text{H}^+$  *NOT*  $\text{HCl}$  *nor*  $\text{HNO}_3$   
 reaction III:  $\text{KMnO}_4 + \text{H}^+$  *NOT*  $\text{HCl}$  *nor*  $\text{HNO}_3$   
 reaction IV:  $\text{Cl}_2 + \text{AlCl}_3$ /accept other halogen carriers *NOT* aq, *nor* u.v.

both I + IV [1]  
both II + III [1]  
 [4]

[Total: 7]

Page 8	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

- 8 (a) (i) Two interlinked spirals *or* chains *or* strands woven round each other [1]  
(ii) By hydrogen bonds between bases [1]  
[2]
- (b) Transcription – (1)DNA/RNA/nucleic acid unravels [1]  
– (2)strand is used as a template [1]  
– (3)mRNA reads the sequence on this strand/  
produces complementary strand [1]
- Translation – (4)mRNA binds to the ribosome [1]  
– (5)tRNA translates the codon from mRNA [1]  
– (6)tRNA carries amino acids to ribosome/adds a.a. to chain [1]  
[**max 4**]
- (c) (i) Disruption of the secondary/tertiary/quaternary/3D structure of the protein  
(could be answered in terms of bonds e.g. hydrogen bonds break) [1]
- (ii) The covalent/peptide bonds in the (protein) chain are too strong [1]  
[2]
- (d) Energy is provided by the breakdown/hydrolysis of adenosine triphosphate (ATP) [1]  
ATP (+ H<sub>2</sub>O) → ADP + P<sub>i</sub> (+ energy) or in words [1]  
ATP is produced during respiration/Krebs cycle/oxidation of glucose, fats or proteins/  
in mitochondria/ADP is recycled [1]  
[3]
- [**Total: 11**]



Page 9	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

- 9 (a) Suitable diagram showing origin of two energy states/or description [1]  
Needs to mention applied magnetic field/electron transfer negates [1]  
Indication that energy difference is in the radio frequency range [1]  
Indication that frequency of absorption *or* gap between the 2 energy states depends on the nature of nearby atoms *or* the chemical environment of the <sup>1</sup>H [1]  
**[3]**
- (b) They do not damage tissues/X-rays harmful/NMR of lower energy [1]  
They are not obscured by bones/skeleton [1]  
They can be tuned to examine particular tissues/tumours/*organs*/protons [1]  
**[max 2]**
- (c) (i)  $M : M+1 = 100/(1.1n)$   

$$n = \frac{0.66 \times 200}{14.5 \times 1.1} = \frac{66}{15.95} = 4.14 = 4 \text{ carbon atoms}$$
 [1]  
Check for 1.1 in divisor, if missing, penalise
- (ii) Singlet at  $\delta$  2 suggests methyl adjacent to C=O [1]  
Quartet at  $\delta$  4 suggests a –CH<sub>2</sub>- group (adjacent to a –methyl group) [1]  
(allow –OCH<sub>2</sub>- )  
Triplet at  $\delta$  1.2 suggests a methyl group (adjacent to a –CH<sub>2</sub>-) [1]  
**G** is ethyl ethanoate (or structure)/if methyl propanoate given here cannot score first marking point [1]  
**[5]**

**[Total: 10]**

Page 10	Mark Scheme	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2007	9701	04

- 10 (a)** Iron is higher in the reactivity series than copper (owtte)/allow use of  $E^\ominus$  [1]
- $\text{Cu}^{2+}(\text{aq}) + \text{Fe}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{Fe}^{2+}(\text{aq})$  [1]  
 If conversion to  $\text{Fe}^{3+}$  given,  $E_{\text{cell}}$  is  $-0.38$  [2]
- (b)** It does not require investment in machinery/labour [1]  
 It requires little energy [1]  
 accept it produces little/no pollution/noise [1]  
 Do not accept comparison with electrolytic method [max 2]
- (c)** The process takes a long time/requires smaller workforce [1]  
 [1]
- (d) (i)** 0.75% is 7.5 kg in every tonne of ore
- Hence 150,000 tonnes of ore yield  $\frac{7.5 \times 150000}{1000}$  tonnes  
 or 1,125 tonnes Cu
- $1125 \times 0.6 = 675$  tonnes (accept 680) [1]
- (ii)**  $450 \times 0.17 = 76.5$  tonnes (accept 77) [1]  
 or  $1125 \times 0.17 = 191.25$  tonnes (accept 191) – this is an ecf if 675 not in (i) [2]
- (e)** Aluminium is too high in the reactivity series/very reactive/aluminium forms bonds with oxygen which are too strong/aluminium ore doesn't exist as sulphide /Fe unable to displace Al [1]  
 [1]
- (f)** Control the pH (*greater* than pH 6.0) [1]  
 Bioremediation/growth of special plants (to remove heavy metals)  
 Other reasonable suggestions such as displacement by a more reactive metal/  
 precipitation/ion exchange [1]  
 [2]  
**[Total: 9]**