Year 12 Chemistry Semester 2 Exam 2008 Solutions

Part 1

1	(c)	**16**	(b)
2	(b)	**17**	(a)
3	(d)	**18**	(c)
4	(a)	**19**	(a)
5	(c)	**20**	(a)
6	(d)	**21**	(a)
7	(d)	**22**	(d)
8	(a)	**23**	(a)
9	(c)	**24**	(b)
10	(c)	**25**	(a)
11	(b)	**26**	(b)
12	(c)	**27**	(d)
13	(b)	**28**	(c)
14	(d)	**29**	(c)
15	(b)	**30**	(b)

[60]

Part 2

1. *Equation:* *[1 mark for correct species, 1 mark for balanced equation]*
Do not penalise for missing or incorrect state symbols
Maximum 1 mark if molecular equation used

Observations: *Need to give 'bulk' of answer for 1 mark*
(at least two observations)

(a) $2\ Al + 2\ OH^- + 6\ H_2O \rightarrow 2\ [Al(OH)_4]^- + 3\ H_2$ [2]

solid dissolves to form colourless solution. colourless gas given off [1]

(b) $2\ H^+ + NiCO_3 \rightarrow Ni^{2+} + CO_2 + H_2O$ [2]

(green) solid dissolves to form green solution. colourless gas given off [1]

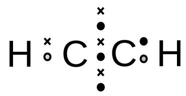
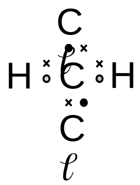
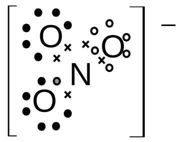
(c) No reaction [3]

(d) $2\ Na + 2\ CH_3CH_3CH_2OH \rightarrow 2\ NaCH_3CH_3CH_2O + H_2$ [2]

solid dissolves to form colourless solution. colourless gas given off [1]

[12 marks]

2.

Species	Structural formula	Shape
Ethyne, C_2H_2	 [1]	Linear [1]
Dichloromethane, $CH_2C\ell_2$	 [1]	Tetrahedral [1]
Nitrate ion, NO_3^-	 [1]	Trigonal planar [1]

[6 marks]

3. n(HCl) = 1.00 x 0.05 = 0.05

c(HCl) = 0.05 / 0.03 = 1.67 [1]

pH = $-\log[H^+]$ = **- 0.22** [1]

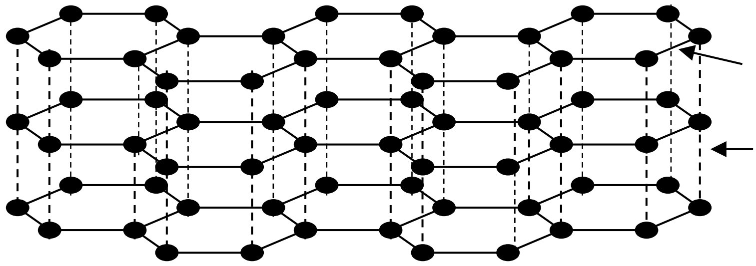
[2 marks]

4.

Description	**Formulae** [need both for 1 mark]	
Two metals that will dissolve in both sodium hydroxide and dilute sulfuric acid.	**Zn**	**Al**
Two metals that will react with dilute nitric acid, but not dilute hydrochloric acid.	**Cu**	**Ag**
Two non-metals that will combine with silicon to form covalent network compounds.	**O_2**	**C**
Two elements that are used as the electrodes during the extraction of aluminium.	**C**	**Fe**
Two elements that are unreactive gases.	**N_2**	**Ar**
The two elements that have the highest electronegativities out of those listed.	**F_2**	**O_2**

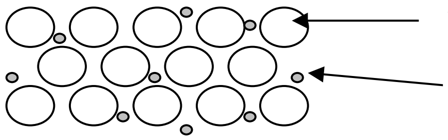
[6 marks]

5. (a) diagram [1] labels[1]



[2 marks]

(b) diagram [1] labels[1]



[2 marks]

(c) The delocalized electrons in the carry the current and enable the zinc to conduct electricity. [1] Because each carbon in graphite is only bonded to three other atoms within the layers, there are valence electrons not used in bonding.[1] These electrons become delocalised and can flow through the graphite when a voltage is applied.

[2 marks]

(d) In a dry cell, the zinc is required to produce electrons for the cell to operate:
$Zn \rightarrow Zn^{2+} + 2\ e^-$ [1]
Graphite is chosen as it is relatively inert, and will not become involved in the (reduction) reaction at the cathode . [1]

[2 marks]

6. (a) $K = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$

[1 mark]

(b) The rate of the forward reaction increases due to the increase in concentration of oxygen. This results in an increase in the concentration of product. [1] The rate of the reverse reaction will therefore increase until the rates equalize, [1] and the concentrations of oxygen and sulfur trioxide become constant.

[2 marks]

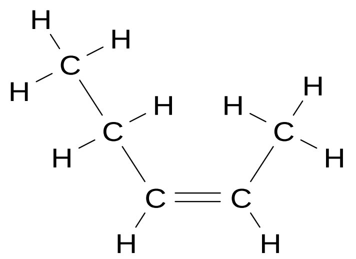
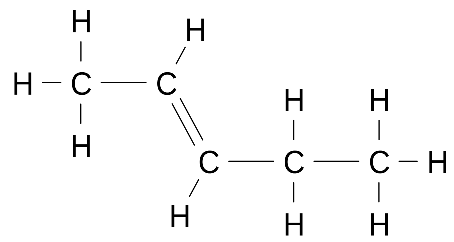
(c) At C

[1 mark]

(d) At this point the temperature has increased, causing the reverse (endothermic) reaction to be more favoured. This will increase the concentration of the reactants, so the value of K will be reduced [1] A and B are at the same temperature, so the value for the equilibrium constant will be the same at these points [1]

[2 marks]

7.

Structure	Structure
	
cis-2-pentene [1]	*trans*-2-pentene [1]

[4 marks]

8. (a) methyl propanoate $CH_3CH_2COOCH_3$ or $C_4H_8O_2$
butanoic acid $CH_3CH_2CH_2COOH$ or $C_4H_8O_2$ [1]

Therefore both have the same molecular formula [1]

[2 marks]

(b) Because butanoic acid contains an O-H bond, hydrogen bonding exists between the molecules. [1] In methyl propanoate there are only dipole-dipole forces between the molecules so it takes less energy to separate them, [1] leading to a melting point below room temperature.

[2 marks]

(c) $5\ CH_3CH_2CH_2CH_2OH + 4\ MnO_4^- + 12\ H^+ \rightarrow 4\ Mn^{2+} + 11\ H_2O + 5\ CH_3CH_2CH_2COOH$

[2 marks]

(d) dilute sulfuric acid is required to provide H^+ [1] for the reduction of the MnO_4^- ion:
($MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + H_2O$)
(Sulfuric acid also used because the sulphate ion will not be involved in a redox reaction)

[1 mark]

(e) Purple to colourless/pale pink

[1 mark]

(f) $CH_3CH_2COOH + CH_3OH \rightarrow CH_3CH_2COOCH_3 + H_2O$

[1 mark]

(g) Concentrated sulfuric acid is used as a catalyst [1] for this reaction. (It also removes water, thus encouraging the forward reaction)

[1 mark]

(e) Fruity smell

[1 mark]

9. [4 marks for correct tests to identify solids]

For example:

Test	**Result**	**Identified**
Add dilute acid to all solids	Those that give off a gas	sodium carbonate, calcium carbonate
Add both of these solids to water	Soluble in water	**sodium carbonate**
	Insoluble in water	**calcium carbonate**
Add water to the other three soilds	Insoluble in water	**zinc hydroxide**
Add sodium carbonate solution to the other two solutions	White precipitate	**barium hydroxide**
	No precipitate	**sodium hydroxide**

[4 marks]

[Up to 3 marks for correct equations]

For example: *equations must relate to the tests shown*

$2\ H^+ + Na_2CO_3 \rightarrow 2\ Na^+ + CO_2 + H_2O$

$2\ H^+ + CaCO_3 \rightarrow Ca^{2+} + CO_2 + H_2O$

$Ba^{2+} + CO_3^{2-} \rightarrow BaCO_3$

[3 marks]

10. (a)

Anode half-equation:	$4\ OH^- \rightarrow O_2 + 2H_2O + 4\ e^-$ [1]
Cathode half-equation:	$[Au(CN)_2]^- + e^- \rightarrow 2\ CN^- + Ag$ [1]
Overall equation:	$4\ OH^- + 4\ [Au(CN)_2]^- \rightarrow 8\ CN^- + 4\ Ag + O_2 + 2\ H_2O$ [1]

[3 marks]

(b) n(Au) = 10.0 / 197.0 = 0.05076 mol [1]
$n(e^-)$ = 0.05076 mol
Q = $0.05076 \times 9.649 \times 10^4$ = 4898 C [1]
t = Q / I = 4898 / 500 **= 9.80 s** [1]

[3 marks]

(c) Towards the steel wool electrode [1]

[1 mark]

(d) The steel wool is dissolved using hydrochloric acid [1]

[1 mark]

Part 3

1. (a) $n(CaC_2O_4)$ = m/M = 9.65 / 128.1 = 0.07533 mol [1]

$n(Ca)$ = 0.07533 mol

$n(CaCO_3)$ = 0.07533 mol [1]

$m(CaCO_3)$ = 0.07533 x 100.09 = 7.540 g [1]

%(Ca) = (7.540 / 15.65) x 100 **= 48.2%** [1]

[4 marks]

(b) $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

n(HCl) = (2 / 1) x $n(CaCO_3)$ = (2 / 1) x 0.07533 [1]

= 0.1507

V(HCl) = n / c = 0.1507 / 2.00 [1]

= 0.07533 L **= 75.3 mL** [1]

[3 marks]

[7 marks]

2. (a) n(Zn) = **m/M** = 2000 / 65.38 = 30.59 mol [1]

Using: $Zn^{2+} + 2e^- \rightarrow Zn$

$n(e^-)$ = 3 x n(Zn) = 2 x 30.59 = 61.18 mol [1]

Q = $n(e^-)$ x 9.649 x 10^4 = 5.90 x 10^6 C [1]

Q = It ∴ I = Q / t

= 5.90 x 10^6 / 3600 = 1639.8 **= 1640 Amps** [1]

[4 marks]

(b) n(Zn) = 30.59 mol M(ZnS) = 97.44

$n(ZnS)_{required}$ = 30.59 mol

$m(ZnS_{pure})_{required}$ = 30.59 x 97.44 = 2981 g [1]

$m(ZnS_{inpure})_{required}$ = (100 / 93) x 2981 = 3205 g

= 3.21 kg [1]

[2 marks]

(c) Reaction: $2\ ZnS + 3\ O_2 \rightarrow 2\ ZnO + 2\ SO_2$ [1]

$n(O_2)$ = (3 / 2) x n(ZnS) = (3 / 2) x 30.59

= 45.885 mol [1]

PV = nRT

∴ V = nRT / P = (45.885 x 8.315 x 673) / 101.3

= 2534.7 **= 2530 L** [1]

[3 marks]

(d) $2\ H_2O(l) \rightarrow O_2(g) + 4\ H^+(aq) + 4e^-$

$n(O_2)$ = (1 / 4) x n(e-) = (1 / 4) x 61.18

= 15.29 mol [1]

$V(O_2)$ = 15.29 x 24.47 **= 374 L** [1]

[2 marks]

(e) E_{cell} = $E_{reduction} - E_{oxidation}$

= - 0.76 – 1.23 = – 1.99 V [1]

∴ minimum voltage **= 1.99 Volts** [1]

[2 marks]

(f) Because the standard reduction potentials only relate to standard conditions. The conditions in this cell are not standard conditions. [1 mark]

[14 marks]

3. (a) $n(NaOH) = c \times V = 0.500 \times 0.0248$

$= 0.0124$ mol [1]

$n(\text{glutamic acid})_{\text{in 20 mL}} = (1 / 2) \times n(NaOH)$

$= 0.00620$ mol [1]

$n(\text{glutamic acid})_{\text{in 100 mL}} = (100 / 20) \times 0.00620$

$= 0.0310$ mol [1]

using $n = m / M$ $M = m / n$ $= 4.56 / 0.0310$

= 147 g mol^{-1} [1]

[4 marks]

(b)

$m(C)_{\text{in 5.00 g}}$	$= (12.01/ 44.01) \times 7.48$	$= 2.041$ g	
% (C)	$= (2.041 / 5.00) \times 100$	$= 40.82\%$	[1]
$m(H)_{\text{in 5.00 g}}$	$= (2.016/ 18.016) \times 2.77$	$= 0.3099$ g	
% (C)	$= (0.3099 / 5.00) \times 100$	$= 6.20\%$	[1]
$m(N)_{\text{in 3.00 g}}$	$= (14.01 / 46.01) \times 0.938$	$= 0.286$ g	
% (N)	$= (0.286 / 3.00) \times 100$	$= 9.52\%$	[1]
% (O)	$= 100 – 40.8 – 6.2 – 9.5$	$= 43.5\%$	[1]

C		**H**		**N**		**O**	
40.8 %		6.2%		9.5 %		43.5%	
40.8 / 12.01		6.2 / 1.008		9.5 / 14.01		43.5 / 16.00	[1]
3.397		6.15		0.678		2.719	
3.397 / 0.678		6.15 / 0.678		0.678 / 0.678		2.719 / 0.678	[1]
5.01	:	9.07	:	1.00	:	4.01	
5	:	9	:	1	:	4	

Empirical Formula is **$C_5H_9NO_4$** [1]

[7 marks]

[11 marks]

4. (a) $n(C_2H_2O_4.2H_2O)$ = 3.451 / 126.068

= 2.737×10^{-2} mol

$c(C_2H_2O_4)$ = 2.737×10^{-2} / 0.500

= 5.475×10^{-2} mol L^{-1} [1]

$n(C_2H_2O_4)_{titration}$ = c x V = $5.475 \times 10^{-2} \times 0.0200$

= 1.095×10^{-3} mol [1]

$2\ MnO_4^-(aq) + 6H^+(aq) + 5\ C_2H_2O_4(aq) \rightarrow 2\ Mn^{2+}(aq) + 8\ H_2O(aq) + 10\ CO_2(g)$

$n(MnO_4^-)$ = (2 / 5) x $n(C_2H_2O_4)$ = (2 / 5) x 1.095×10^{-3}

= 4.380×10^{-4} mol [1]

$c(MnO_4^-)$ = 4.38×10^{-4} / 0.01975 = 2.218×10^{-2} mol L^{-1}

= 2.22×10^{-2} mol L^{-1} [1]

[4 marks]

(b)

	Burette readings (mL)		
	1	2	3
Final volume	14.40	28.55	42.70
Initial volume	0.00	14.40	28.55
Titre	**14.40**	**14.15**	**14.15**

$MnO_4^-(aq) + 8\ H^+(aq) + 5\ Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5\ Fe^{3+}(aq)$

$n(MnO_4^-)_{titration}$ = 0.02218 x 0.01415 = 3.138×10^{-4} [1]

$n(Fe^{2+})_{titration}$ = (5 / 1) x $n(MnO_4^-)$ = (5 / 1) x 3.138×10^{-4}

= 1.569×10^{-3} mol [1]

$n(Fe^{2+})_{total}$ = (250 / 25) x 1.565×10^{-3} = 1.569×10^{-2} [1]

$M(FeSO_4.7H_2O)$ = 278.022

$m(FeSO_4.7H_2O)$ = 1.569×10^{-2} x 278.022 = 4.362 g [1]

% purity ($FeSO_4.7H_2O$) = (4.36 / 4.57) x 100

= 95.4% [1]

[5 marks]

[9 marks]

5. (a) $3\ NaHCO_3(s) + C_6H_8O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3\ H_2O(\ell) + 3\ CO_2(s)$

$n(NaHCO_3) = 1.700 / 84.008 = 0.02023$ mol

$n(C_6H_8O_7) = 0.300 / 192.124 = 1.561 \times 10^{-3}$ mol [1]

$n(NaHCO_3)_{used} = (3 / 1) \times n(C_6H_8O_7) = (3 / 1) \times 1.561 \times 10^{-3}$

$= 4.68 \times 10^{-3}$ mol [1]

$n(NaHCO_3)_{excess} = 0.02023 - 4.68 \times 10^{-3} = 0.01555$ mol [1]

$c(NaHCO_3) = 0.01555 / 0.270 =$ **5.76×10^{-2} mol L^{-1}** [1]

$n(C_9H_8O_4) = 0.325 / 180.154 = 1.80 \times 10^{-3}$ mol

$c(C_9H_8O_4) = 1.80 \times 10^{-3} / 0.270 =$ **6.68×10^{-3} mol L^{-1}** [1]
[5 marks]

(b) $n(HCl)_{original} = 1.60 \times 0.650 = 0.104$ mol

$n(HCl)_{after\ Tim\ Tams} = 2.0 \times 0.650 = 0.130$ mol [1]

$n(HCl)_{excess} = 0.130 - 0.104 = 0.026$ mol [1]

$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

$n(NaHCO_3) = n(HCl) = 0.026$ [1]

$n(NaHCO_3)_{in\ one\ tablet} = 0.0156$ mol

number of tablets required $= 0.026 / 0.0156 = 1.67$

≈ 2 tablets [1]
[4 marks]

[9 marks]

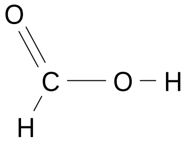
Part 4 (20 Marks) *Model Answer*

It is not expected that students need to cover all points in order to obtain maximum marks. Credit should be given for accurate use of equations, diagrams and examples. No credit is given for repeating information given in the question, nor for areas of chemistry not mentioned in the question.

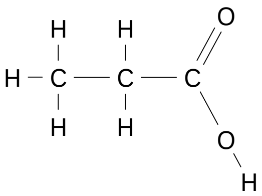
Carboxylic Acids

Examples of Carboxylic Acids

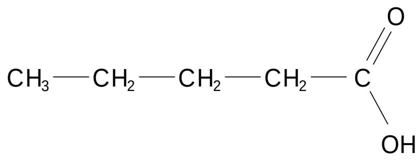
Methanoic acid



Propanoic acid



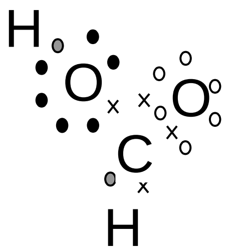
Pentanoic acid



Carboxylic acids can be represented as R-COOH where R represents an alkyl group such as $-CH_3$ (methyl) or $–C_2H_5$ (ethyl) or in the case of methanoic acid, just H.

Structure of carboxylic acid group

This group has a **planar structure**. This can be explained by considering the valence electrons around the carbon atom. The example below shows methanoic acid. The central carbon completes its outer shell by pairing up with four other electrons. However, as it is forming a double bond with one of the oxygen atoms, this double bond acts as a single area of electrons (or charge cloud). This means that there are in affect three charge clouds, with no non-bonding electrons on the valence shell of the carbon. To maximise the distribution of these electrons, the molecule exhibits a trigonal planar structure with bond angles of 120°.



Ionisation of carboxylic acids

When carboxylic acids are added to water there is the possibility of the molecule ionising to produce hydrogen ions and carboxylate ions. The carboxylic acids will not be totally ionised, as this process is reversible. This can be shown as a general reaction as shown.

$$RCOOH(aq) \rightleftarrows RCOO^-(aq) + H^+(aq)$$

Example:

$CH_3COOH(aq) \rightleftarrows CH_3COO^-(aq) + H^+(aq)$
ethanoic acid ethanoate

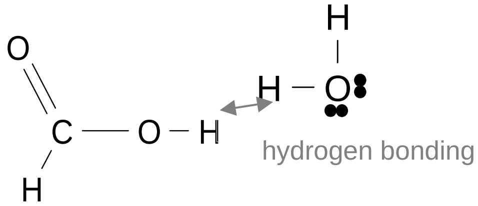
Because the substances are only partially ionised, carboxylic acids tend to be weak acids. The equilibrium constant for these reactions such as:

$$K = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

will be very low, because the concentrations of the ions will be considerably lower than the concentration of the acid molecules.

Solubility

Because of the O-H bond in the carboxylic acid molecules, hydrogen bonding can occur between molecules. It can also occur between the carboxylic acid molecules and water molecules which increases their solubility in water.



Formation of esters from carboxylic acids

When carboxylic acids react with alcohols in the presence of concentrated sulfuric acid a group of organic compounds called esters are formed. The general reaction can be described as follows.

carboxylic acid + alcohol → ester + water

These reactions are described as **condensation reactions** as they result in the formation of water as a by-product of the reaction. The sulfuric acid acts as a catalyst in the reaction. The sulfuric acid can also increase the yield of the reaction as it removes the water from the system.

Examples of these reactions

$CH_3OH + CH_3CH_2CH_2COOH \rightarrow CH_3CH_2CH_2COOCH_3 + H_2O$
methylbutanoate

$CH_3CH_2OH + CH_3COOH \rightarrow CH_3COOCH_2CH_3 + H_2O$
ethylethanoate

Carboxylate ions as surfactants

Carboxylate ions formed from the breakdown of oils tend to have very long alkyl groups attached to the polar carboxylate 'end' of the molecule.

CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2-**COO^-**

non-polar 'tail' ***polar 'head'***

The long alkyl group acts as non-polar 'tail' of the molecule. This structure with non-polar and polar regions within the molecule gives the substance the ability to act as a surfactant. This allows it to be used as a soap, as the molecule is attracted to non-polar 'dirt' or grease, and a polar solvent, such as water. However, only certain carboxylate **ions** will show this behaviour. It is not a major property of the carboxylic acids themselves.

Diprotic carboxylic acids

Some carboxylic acids contain more than one acid group. These substances can be used in condensation polymerisation reactions when they react with diols (alcohols with two alcohol functional groups) to form polyesters. The presence of the two groups on each molecule allows chain reactions to occur, with reactions happening on both ends of the growing polymer chain. For example: