THE SCHOOL FOR EXCELLENCE
UNIT 3 CHEMISTRY 2009
COMPLIMENTARY WRITTEN EXAMINATION 1 - SOLUTIONS

SECTION A - MULTIPLE CHOICE QUESTIONS

QUESTION 1 Answer is B

Note: $H_3PO_4 \rightarrow 3H^+ + PO_4^{3-}$ i.e. Each H_3PO_4 produces 4 ions.

$$number(ions) = n \times N_A \times 4 = 3 \times 6.02 \times 10^{23} \times 4 = 7.224 \times 10^{24}$$

QUESTION 2 Answer is D

$$m(Na_2SO_4) = 15 - 7.05 = 7.95\,g$$

$$n(Na_2SO_4) = \frac{m}{M} = \frac{7.95}{142.1} = 0.0559\,mol$$

$$n(H_2O) = \frac{m}{M} = \frac{7.05}{18} = 0.3917\,mol$$

$n(Na_2SO_4) : n(H_2O)$

$0.0559 : 0.3917$

$1 : 7$

QUESTION 3 Answer is D

The oxidation number of H in $LiAlH_4$ is -1. **Note:** Oxidation numbers may be fractions and decimal values as well.

QUESTION 4 Answer is C

Broad endpoints are often obtained in the titration involving a weak species. In such cases, a back titration is used.

QUESTION 5 Answer is A

QUESTION 6 Answer is A

QUESTION 7 Answer is A

The organic compound with the lowest solubility in octane is the species that has the shortest chain length i.e. A.

QUESTION 8 Answer is D

QUESTION 9 Answer is A

Addition reactions involving alkenes readily occur to produce 1 product. To produce additional products from the chloroalkane produced, UV light would be required. Therefore, only 1 product results.

QUESTION 10 Answer is D

Section A corresponds to the UV region. This radiation is used to measure the concentration of colourless solutions such as organic compounds.

Note: The order of increasing radiation wavelength is: UV Vis IR Radiowaves

QUESTION 11 Answer is B

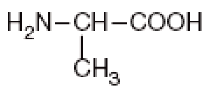
QUESTION 12 Answer is C

QUESTION 13 Answer is A

Molecule is an ester with characteristic absorptions at 1735 cm^{-1} (C=O) and 1250 cm^{-1} (C-O). **Note:** Look for the presence and absence of bands characteristic to the common functional groups.

QUESTION 14 Answer is A

Formula is $C_3H_7NO_2$:



QUESTION 15 Answer is C

QUESTION 16 Answer is A

AAS is used to determine the concentration of metal atoms in samples.

QUESTION 17 Answer is C

QUESTION 18 Answer is B

QUESTION 19 Answer is D

QUESTION 20 Answer is B

SECTION B – SHORT ANSWER QUESTIONS

QUESTION 1

a. (i) $NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2CO_{3(aq)}$ OR

$NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$ (1 mark)

(ii) If the baking soda is 100% pure sodium hydrogen carbonate:

N = m/M = 2.06/(23.0+1.0+12.0+3x16.0) = 2.06/84 = 0.0245 mol

So making this up to 250 mL: c= n/v = 0.0245/0.250 = 0.0981 M (1 mark)

As the ratio of $NaHCO_3$ and HCl in the equation is 1:1, $n(HCl)$ delivered from the burette will be equal to $n(NaHCO_3)$. As the concentration of the presumed 100% sodium hydrogen carbonate is less than the concentration of HCl being used, the volume of HCl required for the titration will be greater than the volume of $NaHCO_3$ present i.e. at least $20\,mL$. Therefore, a $20\,mL$ burette will not be sufficient for this titration (1 mark).

b. The products at the equivalence point of this titration are acidic, meaning that an indicator which changes colour in the acidic region should be used. Phenolphthalein changes colour in the alkaline region and hence is not a good choice for this titration (1 mark).

c. (i) John has included the 24.36 mL which should have been excluded as an outlier and a trial titration (1 mark). The average titre being used is therefore higher than what it should be.

(ii) n($NaHCO_3$) in 20ml aliquot = n(HCl) =0 .02404 x 0.100 = 0.002404 mole
n($NaHCO_3$) in 250 mL flask = 0.002404 X 250/20 = 0.03005 mole (1 mark)

Mass($NaHCO_3$) = 0.03005x84 = 2.5242 g

% Purity = (2.5242x100)/2.06 = 126% (3 sf) (1 mark)

(iii) The wrong indicator was used for the titration (1 mark). The indicator used would change colour after the equivalence point of the reaction. This means that a greater volume of HCl than that required would be delivered from the burette, resulting in the n($NaHCO_3$) and mass($NaHCO_3$) calculated being higher than the true values. This would result in a higher calculated % than the true value (1 mark).

Using a higher average titre would have the same effect on the calculated percentage (1 mark).

QUESTION 2

a. (i) To act as a site for vapour to condense.
(ii) Bubble caps and trays.

b. (i) The order in which the components would be collected is dependent on the molar mass. The lower molar mass components would be collected first. Therefore, the order would be:

Helium (4)
Neon (20)
Nitrogen (28)
Oxygen (32)
Argon (36)
Carbon dioxide (44)

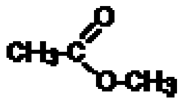
b. Molecules are non polar, therefore, the interparticle bond that determines the boiling point is the weak dispersion force (1 mark).

The sum strength of the dispersion forces between the non polar molecules being separated increase as the molar mass increases and consequently the boiling point (boiling temperature) increases (1 mark). At the top of the tower the temperature is lower and the substances with the lower Mr are collected (1 mark).

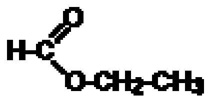
QUESTION 3

a. **propanoic acid**

methyl ethanoate



ethyl methanoate



(1 mark for each correctly drawn isomer and its correct systematic name).

b. (i) Peak at m/z 74 is $C_3H_6O_2^+$ (1 mark – but answer must carry a positive charge). The peak at m/z 75 is also $C_3H_6O_2^+$ with one of the carbon atoms being the ^{13}C isotope (1 mark).

(ii) The most stable fragment is the one with the highest abundance.
i.e. The fragment with m/z 43 (1 mark).

(iii) Methyl ethanoate (1 mark).

The fragment at m/z 43 was likely produced from $C_3H_6O_2^+$ by the removal of a $-O-CH_3$ group and which is only present in methyl ethanoate. (1 mark)

QUESTION 4

a. A = $CH_3C(CH_3)_2OH$

D = $CH_3CH_2CH_2CH_2OH$ (1 mark)

Branching reduces the net strength of dispersion forces formed between molecules, hence these molecules display lower boiling temperatures, are more volatile, and are hence eluted earlier in the GLC (1 mark).

b. (i) Two peaks in the C-13 NMR spectrum indicate that the molecule displays 2 different carbon environments.

There are 4 isomers with molecular formula C_4H_9OH .

A = $CH_3C(CH_3)_2OH$

D = $CH_3CH_2CH_2CH_2OH$

The other two molecules are $CH_3CH_2CHOHCH_3$ and $CH_3CH(CH_3)CH_2OH$, which have 4 and 3 different carbon environments respectively. Therefore:

B = $CH_3CH(CH_3)CH_2OH$ (1 mark)

(ii) 6:1:2:1 OR 1:2:1:6 (1 mark)

Chemical Shift (ppm)	Relative Intensity of Signal
0.9	6
2.0	1
4.0	2
5.0	1

c. When in different states, water molecules have different energies and hence require different energies to move from one vibrational energy level to another, absorbing different quanta of radiation from the infra red region.

QUESTION 5

a. These peaks are caused by the C=O groups, of which there are two in the structure of acetylsalicyclic acid (1 mark). As these C=O groups are in different chemical environments, the energies required to cause changes in vibrational energy levels also changes, resulting in two separate peaks (1 mark).

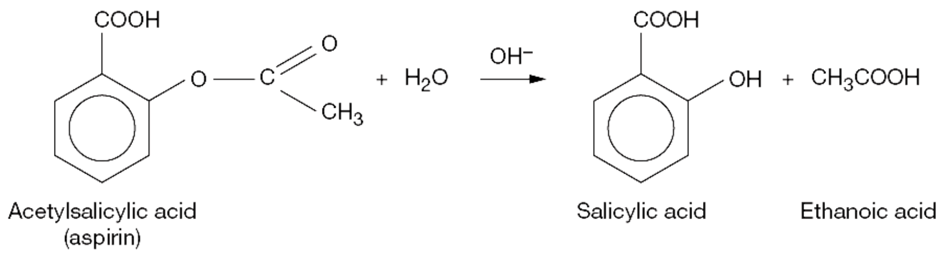
b. (i) The salicyclic acid molecule, although different from acetylsalicyclic acid, also displays 6 different hydrogen environments. Therefore, both spectra would display the same number of peaks (1 mark).

(ii) The peak will appear at a shift value smaller than 11.5 ppm (1 mark) as the chemical environment of H in COOH in salicyclic acid is less polar. The shielding around the protons being measured increases, hence the amount of electromagnetic radiation required for resonance increases, meaning that a peak will be produced at a lower shift value (1 mark).

Note: In general, the more polar the environment around the nucleus being measured, the higher the chemical shift.

(iii) The 4 middle peaks represent the hydrogen atoms attached to the benzene ring. These atoms share a very similar environment – but there are differences, which are reflected by the presence of 4 distinct peaks (1 mark).

c.



QUESTION 6

a. (i) Bond at A: Hydrogen bonding
Bond at B: Phosphodiester link

(ii) To separate the gene into separate nucleotides, 29 water molecules would be required.

Each nucleotide (30) requires 2 water molecules for complete hydrolysis to individual sugar, phosphate and base units, meaning that a total of 60 water molecules would be required for this process.

In total, 29 + 60 = 89 water molecules would be required.

b. (i) DNA and its fragments are negatively charged and will only migrate to the positive terminal. Hence samples are applied at the negative terminal.

(ii) Separation is based on size with the lighter components travelling further. As guanine is a larger base than thymine, C would be represent thymine containing fragments, A would best represent guanine containing fragments (1 mark) and the fragment containing both bases would be represented by B.

c. (i) Suspect 3.

(ii) Further fingerprints using different probes to detect different gene sequences needs to be employed before DNA fingerprinting can be used conclusively.

There are many characteristics/gene sequences that are shared across different populations (eg. race), therefore, additional probes are required.

QUESTION 7

a. (i)

$$
\begin{array}{l}
\qquad\qquad\quad O \\
\qquad\qquad\quad // \\
CH_2 - O - C - (CH_2)_7CHCH(CH_2)_7CH_3 \\
| \qquad\qquad\quad O \\
| \qquad\qquad\quad // \qquad\qquad\qquad\qquad\qquad\qquad + 3H_2O_{(l)} \\
CH - O - C - (CH_2)_7CHCH(CH_2)_7CH_3 \\
| \qquad\qquad\quad O \\
| \qquad\qquad\quad // \\
CH_2 - O - C - (CH_2)_{14}CH_3
\end{array}
$$

$$\downarrow$$

$$C_3H_8O_3 + 2COOH(CH_2)_7CHCH(CH_2)_7CH_3 + COOH(CH_2)_{14}CH_3$$

b. **i.** One of two answers accepted:

$$CH_3(CH_2)_7CHCH(CH_2)_7COOH + CH_3OH_{(l)} \rightarrow CH_3(CH_2)_7CHCH(CH_2)_7COOCH_{3(l)} + H_2O_{(l)}$$

$$CH_3(CH_2)_{14}COOH_{(l)} + CH_3OH_{(l)} \rightarrow CH_3(CH_2)_{14}COOCH_{3(l)} + H_2O_{(l)}$$

ii. One of two answers accepted:

$$2C_{18}H_{34}O_{2(l)} + 33O_{2(g)} \rightarrow 36CO_{(g)} + 34H_2O_{(l)}$$

$$C_{16}H_{32}O_{2(l)} + 15O_{2(g)} \rightarrow 16CO_{(g)} + 16H_2O_{(l)}$$

c. (i) Reagent A is $H_{2(g)}$.
Substance B is a catalyst (platinum).

(ii) Answer is B.

QUESTION 8

The molecular formula of substance V suggests that the molecule is an alcohol.

The molecular formulae of substance X and Y suggest that the molecules are either an ester or carboxylic acid.

The fact that V is oxidised to X suggests that V is an alcohol and that X is a carboxylic acid.

The dehydration reaction suggests that V is an alkanol. Hence its systematic name is 1-propanol.

X is 1-propanoic acid.

Alkanols are oxidised by strong oxidants such as acidified potassium dichromate to produce carboxylic acids. Therefore, Y must be 1-ethanoic acid.

Compound Z is the ester propylethanoate.

Using the given molecular formula, the product, W, formed during the dehydration of V can be identified as prop-1-ene.

(1 mark for each molecule correctly identified).

QUESTION 9

a. $8H^{+}_{(aq)} + Cr_2O^{2-}_{7(aq)} + 3H_2C_2O_{4(aq)} \rightarrow 6CO_{2(ag)} + 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$

b. $n = \frac{PV}{RT} = \frac{(101.325 \times 1.07) \times (5.00)}{8.31 \times (273 + 75)} = 0.187\ mol\ CO_2$ (1 mark)

$n(K_2Cr_2O_7) = \frac{1}{6} \times n(CO_2) = 0.0312\ mol$

$m(K_2Cr_2O_7) = n \times M = 0.0312 \times 294.2 = 9.18\ g$ (1 mark)

c. $n(K^+) = 2 \times n(K_2Cr_2O_7) = 2 \times 0.0312 = 0.0624\ mol$

$m(K^+) = n \times M = 0.0624 \times 39.1 = 2.43984\ g$ (1 mark)

$2.43984\ g\ K^+ / 25\ L$

$2.43984\ g\ K^+ / 25,000\ mL$

As $1\ mL = 1\ g$

$2.43984\ g\ K^+ / 25,000\ g$

$2.43984 \times 40\ g\ K^+ / 1 \times 10^6\ g$

$97.5936\ g\ K^+ / 1 \times 10^6\ g$

$97.6\ ppm$ (1 mark)