THE SCHOOL FOR EXCELLENCE
UNIT 3 CHEMISTRY 2008
COMPLIMENTARY WRITTEN EXAMINATION 1 - SOLUTIONS

SECTION A - MULTIPLE CHOICE QUESTIONS

QUESTION 1 Answer is B

QUESTION 2 Answer is B

QUESTION 3 Answer is D

QUESTION 4 Answer is D

QUESTION 5 Answer is B

QUESTION 6 Answer is B

QUESTION 7 Answer is C

QUESTION 8 Answer is B

QUESTION 9 Answer is A

Decanoic acid has the lowest chain length hence the lowest solubility in water.

QUESTION 10 Answer is B

Asparagine would form a positively charged molecule. Glycine and histidine will form a neutrally charged molecule. Glutamic acid will form a negatively charged molecule and hence move towards the positive terminal.

QUESTION 11 Answer is B

QUESTION 12 Answer is B

Choose the fatty acid that displays the greatest degree of unsaturation as this species will exist in the least solid form at romm temperature.

QUESTION 13 Answer is B

QUESTION 14 Answer is D

QUESTION 15 Answer is C

QUESTION 16 Answer is C

Components undergo a continual process of adsorption (not absorption) and desorption.

QUESTION 17 Answer is A

Choose the wavelength that gives maximum absorbance – but in a region where Sugar X exclusively absorbs.

QUESTION 18 Answer is D

QUESTION 19 Answer is A

The compound must have three chlorine atoms in it which leaves room for only one fluorine atom. Options B, C and D are therefore impossible.

QUESTION 20 Answer is A

Overall spin will only be observed in nuclei that have an odd number of nucleons such as ^{13}C . ^{12}C has an even number of nucleons hence no overall spin.

SECTION B – SHORT ANSWER QUESTIONS

QUESTION 1

a. Calculate the amount in mole of Na_2CO_3: $n = \frac{m}{M} = \frac{1.336}{106} = 0.012604\ mol$

Calculate the concentration of Na_2CO_3: $n = cV$

$$c = \frac{n}{V} = \frac{0.012604}{0.25} = 0.050416 = 0.0504\ M$$

b. $Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

$$n(Na_2CO_3)_{in\ 20ml} = cV = 0.0504 \times 0.02 = 0.001008\ mol$$

$$n(HCl) = 2 \times n(Na_2CO_3) = 2 \times 0.001008 = 0.002016\ mol$$

$$c(HCl) = \frac{n}{V} = \frac{0.002016}{0.0192} = 0.106\ M$$

c. **Note:** In this titration, the known is in the conical flask and the unknown is in the burette.

(i) Any indicator on the formula sheet which undergoes a colour change between pH 4 and pH 6.5 (the vertical region of the curve). For example, methyl red.

(ii) As the end point occurs well before the equivalence point, a lower volume than that required will be recorded.

$$\therefore \uparrow c = \frac{n}{V \downarrow}$$

The calculated concentration of unknown will therefore be **HIGHER THAN** the expected value.

(iii) The weighed mass will contain **MORE** sodium carbonate than expected.

Therefore, the concentration of the standard solution will be **HIGHER THAN** expected.

A **LARGER** volume will need to be delivered from the burette to neutralise the solution in the conical flask.

$$\therefore \downarrow c = \frac{n}{V\uparrow}$$

The calculated concentration of unknown will therefore be **LOWER THAN** the expected value.

d. $NH^{+}_{4(aq)} + OH^{-}{}_{(aq)} \rightarrow NH_{3(aq)} + H_2O_{(l)}$

(i) $NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

$$n(HCl) = cV = 0.106 \times 0.02225 = 0.0023585\, mol$$

$$n(NaOH)_{excess} = n(HCl) = 0.0023585\, mol$$

$$n = cV = 0.150 \times 0.020 = 0.003\, mol$$

$$\begin{aligned} n(NaOH)_{reacted} &= n(NaOH)_{initial} - n(NaOH)_{excess} \\ &= 0.003 - 0.0023585 \\ &= 0.0006415 = 6.42 \times 10^{-4}\ mol \end{aligned}$$

(ii) $n(NH_4^+) = n(NaOH)_{reacted} = 0.0006415\, mol$ (in 20 ml)

Correct for scaling factors.

$0.0006415\, mol$ in 20 ml

In 250 ml $= \dfrac{250}{20} \times 0.0006415 = 0.00801875\, mol$

$\%N$ by mass $= \dfrac{mass\ \ of\ \ N}{mass\ \ of\ \ fertiliser} \times 100$

$$n(NH_4^+) = n(N) = 0.00801875\, mol$$

$$m = n \times M \quad = 0.00801875 \times 14 = 0.1122625\ g$$

$$\%N = \frac{0.1122625}{1.50} \times 100 = 7.48\%$$

QUESTION 2

a. A = Butene
C = Butanoic acid
E = Ethyl butanoate

Note: B = Bromobutane
D = Butanol
F = Sodium butanoate

b. (i) Compound B

$$CH_3CH_2CHCH_{2(aq)} + HBr_{(g)} \rightarrow CH_3CH_2CH_2CH_2Br_{(aq)}$$

(ii) Compound D

$$CH_3CH_2CH_2CH_2Br_{(aq)} + NaOH_{(aq)} \rightarrow CH_3\left(CH_2\right)_3 OH_{(aq)} + NaBr_{(aq)}$$

(iii) Compound F

$$CH_3\left(CH_2\right)_2 COOH_{(aq)} + Na_2CO_{3(aq)} \rightarrow CH_3\left(CH_2\right)_2 COONa_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

QUESTION 3

a. (i) $C_3H_6O_6^+$. Species must be positively charged to obtain the full mark.

(ii) The peak corresponding to mass/charge ratio 74 is caused by the ionised molecule of B consisting of the ^{12}C isotope. The Peak at 75 is caused by the molecular ion consisting of one ^{13}C atom.

(ii) Isomers display the same number of each type of atom, therefore, the mass/charge ratio of the molecular ion would be the same. However, due to different structural arrangements, different fragments will be obtained. **Note:** The m/z of the parent ion will be the same in all isomers, however, fragments and their masses will be different.

Therefore, mass spectra of molecules will vary amongst isomers.

Note: As the relative abundance of the main molecular ion is 74 g/mol, the molecular formula is equivalent to the empirical formula of the compound.

b. (i) The very broad dip at about $3000\,cm^{-1}$ is due to $O-H$.
The dip at about $1700\,cm^{-1}$ is due to $C=O$.

The molecule is therefore most likely to be a carboxylic acid.

(ii) Due to differences in the arrangement of atoms, different groupings and environments may be created, resulting in different IR spectra.

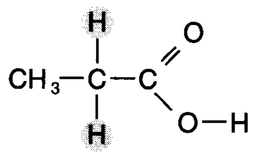
c. (i) The peak at 0 is caused by the reference compound TMS (tetramethylsilane), which acts as the reference from which all shifts are reported.

(ii) The peak areas are in the ratio 1:2:3 (from left to right) indicating how many of each type of hydrogen atom is present in the molecule.

The shift at about 11.5 ppm suggests the presence of a H atom in $R-COOH$. As the relative area is 1 – there is 1 such H atom in this environment.

The shift at about 2.6 ppm suggests the presence of a H atom in $R-CH_2-COOH$. As the relative area is 2 – there are 2 such H atoms in this environment.

The shift at about 1 ppm suggests the presence of a H atom in $R-CH_3$. As the relative area is 3 – there are 3 such H atoms in this environment.



(iii) Different spectra would be obtained as different chemical environments would result when atoms within in a molecule were arranged in different ways.

QUESTION 4

a. (i) $Cr_2O_{7(aq)}^{2-} + 14H_{(aq)}^{+} + 6e^{-} \rightarrow 2Cr_{(aq)}^{3+} + 7H_2O_{(l)}$

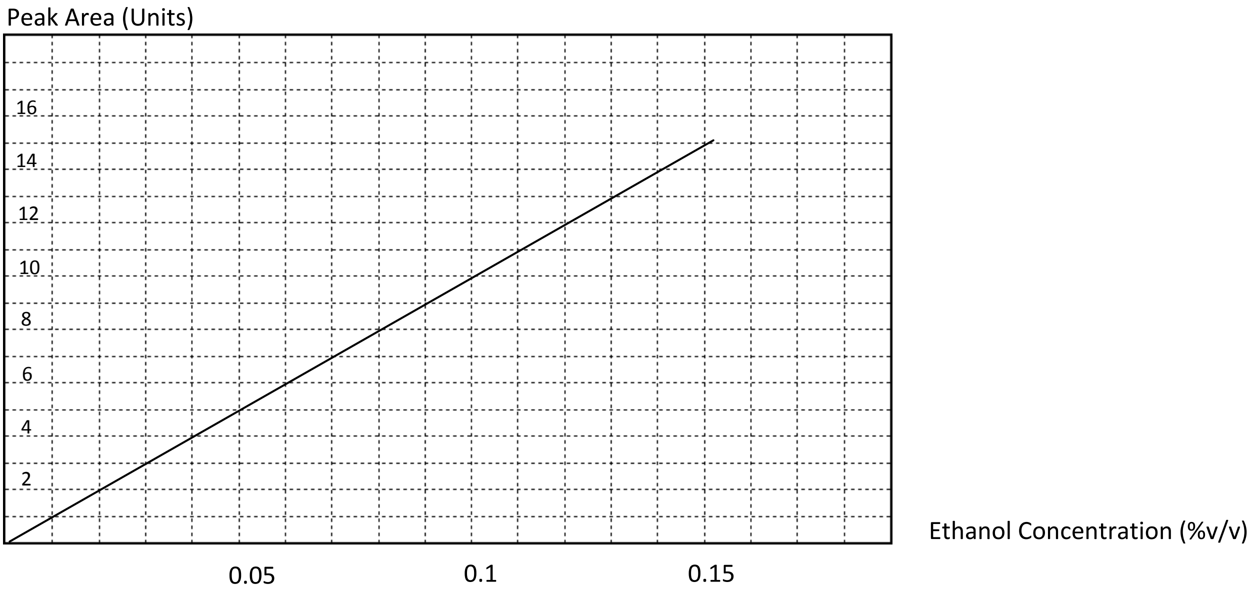
(ii) $CH_3CH_2OH_{(aq)} + H_2O_{(l)} \rightarrow CH_3COOH_{(aq)} + 4H_{(aq)}^{+} + 4e^{-}$

(iii) $2Cr_2O_{7(aq)}^{2-} + 28H_{(aq)}^{+} + 12e^{-} \rightarrow 4Cr_{(aq)}^{3+} + 14H_2O_{(l)}$

$3CH_3CH_2OH_{(aq)} + 3H_2O_{(l)} \rightarrow 3CH_3COOH_{(aq)} + 12H_{(aq)}^{+} + 12e^{-}$

$$3CH_3CH_2OH_{(aq)} + 2Cr_2O_{7(aq)}^{2-} + 16H_{(aq)}^{+} \rightarrow 3CH_3COOH_{(aq)} + 4Cr_{(aq)}^{+} + 11H_2O_{(l)}$$

b. (i)



(ii) $0.06\,\%\,v/v$. **Note:** This value does NOT represent the BAC as defined in b. (iii).

(iii) Find the mass of ethanol in $0.06\,ml$.

Motorist $= 0.06\,\%v/v$
$= 0.06\,ml\ ethanol / 100\,ml\ blood$

As $d = \dfrac{m}{V}$ then $m = d \times V = 0.789 \times 0.06 = 0.04734\,g$

Motorist $= 0.04734\,g\ ethanol / 100\,ml\ blood$
$= 47.34\,mg\ ethanol / 100\ blood$

The BAC of the motorist is below the legal limit.

(iv) $n(K_2Cr_2O_7) = \frac{2}{3} \times n(CH_3CH_2OH) = \frac{2}{3} \times \left(\frac{0.04734}{46}\right) = 0.00068609\ mol$

For $1\,ml$ blood: $n(K_2Cr_2O_7) = \frac{0.00068609}{100} = 6.861 \times 10^{-6}\ mol$

$$250\ ppm\ (K_2Cr_2O_7) = 250\ g\ K_2Cr_2O_7\ /1 \times 10^6\ g\ solution$$

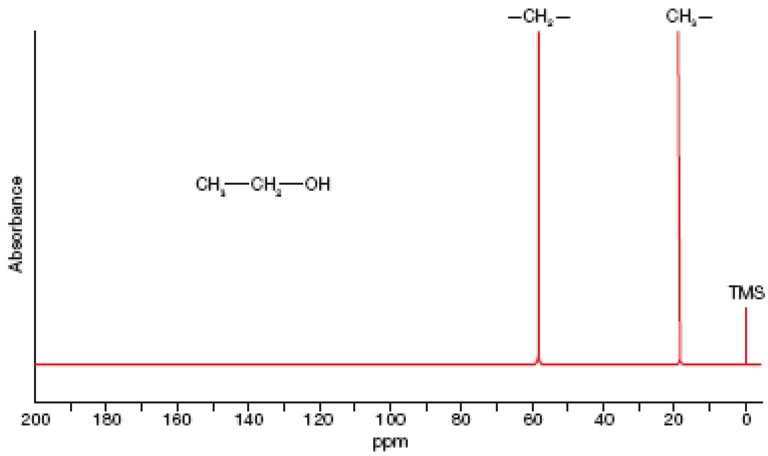
$$= \frac{250}{294.2}\ mol\ K_2Cr_2O_7\ /1 \times 10^6\ ml\ solution$$

$$= 0.84976\ mol\ K_2Cr_2O_7\ /1 \times 10^6\ ml\ solution$$

Cross multiplying: $V = 8.07\ ml$

c. There are 2 different carbon environments, therefore, curve must consist of two peaks with the same heights (as the same number of carbons are present in each different environment).

One peak is to be located between 8 and 25 ppm. The second peak is to be drawn between 50 and 90 ppm. For example:



QUESTION 5

a. (i) Butanoic acid, Methanol, Concentrated H_2SO_4.

(ii) Methylbutanoate.

(iii) C

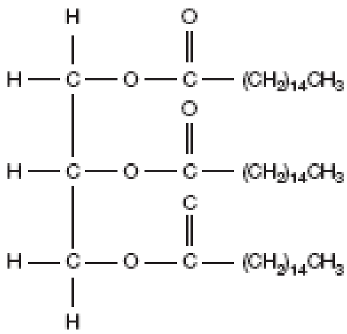
b. Distillation involves the separation of mixtures on the basis of their boiling points**.**

The mixture of liquids is heated in the distillation flask to produce a vapour that rises up the fractionating column.

The more volatile liquid (the liquid with the lower boiling point) will evaporate first and moves up the fractionating column until it reaches a point where the temperature is low enough for condensation to occur. After a series of condensation-evaporation cycles, the lower boiling point component can be separated from the remaining mixture in pure form. This process can be repeated at higher temperatures to then isolate the next lowest boiling point component etc.

In the case of the production of this ester, the order of increasing boiling points and hence separation would be: Methanol, then butanoic acid and finally the ester.

c. (i)



(ii) Heat with methanol in the presence of concentrated sulfuric acid as catalyst.

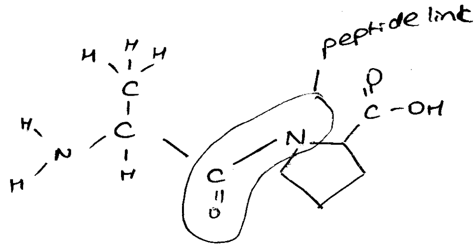
$$CH_3-OH + H-O-\overset{\overset{\displaystyle O}{\|}}{C}-(CH_2)_{14}CH_3 \longrightarrow CH_3-O-\overset{\overset{\displaystyle O}{\|}}{C}-(CH_2)_{14}CH_3 + H_2O$$

QUESTION 6

a. (i) Circle A, B and D. The low activity at low temperatures is due to low reaction rates – not denaturation.

(ii) The protein chain in an enzyme molecule is folded so that it has a particular shape, and it is this shape that determines whether the enzyme can interact with the appropriate substrate. If the 3-D shape of the protein changes, the substrate will no longer be able to fit into the active site, and the enzyme will lose its ability to catalyse the reaction.

b. (i) This is a nasty question. Proline is often viewed as not being a true 2-amino acid as the N containing group exists as NH as opposed to NH_2. However, it reacts in the same manner as other amino acids, but the peptide linkage is CON instead of $CONH$.



(ii) Circle the peptide link (CON), the amino group (NH_2) and carboxy group ($COOH$).

c. (i) A: Dispersion forces – Tertiary Structure.

(ii) B: Hydrogen bonding – Tertiary Structure (Note: The H bonding is drawn between Z groups – not the functional groups located directly off the central carbon in 2-amino acids).

(iii) C: A: Ionic interactions – Tertiary Structure.

QUESTION 7

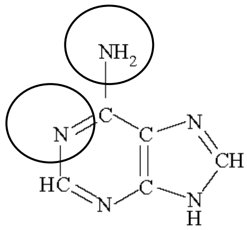
a. (i) Circle A. Proteins in the body are produced from α or 2 amino acids.

(ii) Circle E and F. Note: Molecule D is a sugar but forms the component of nucleotides rather than carbohydrates.

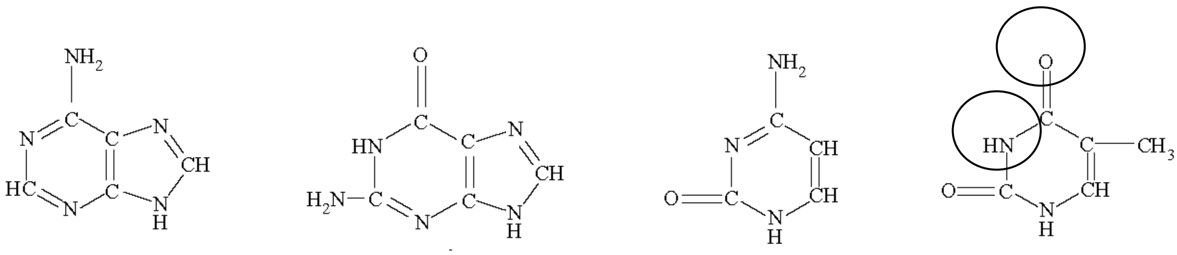
(iii) Circle I.

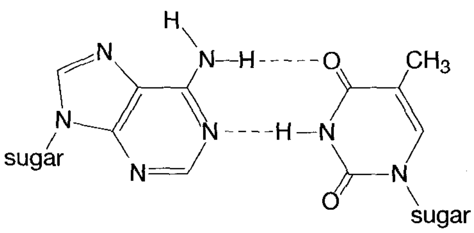
(iv) Circle D.

b. **Molecule C**



Complementary Base:





adenine (A) thymine (T)

c. Molecule C is adenine which forms 2 hydrogen bonds with thymine. As it produces fewer hydrogen bonds when pairing with its complementary base as compared to the pairing bonds involved between cytosine and guanine, a strand mainly consisting of A-T would display fewer forces, hence lower temperatures would be required for melting. The curve that best represents this scenario is A.