



THE SCHOOL FOR EXCELLENCE
UNIT 3 CHEMISTRY 2010
COMPLIMENTARY WRITTEN EXAMINATION 1 - SOLUTIONS

SECTION A - MULTIPLE CHOICE QUESTIONS

QUESTION 1 Answer is A

QUESTION 2 Answer is B

QUESTION 3 Answer is D

A $10 \mu\text{g.L}^{-1}$ $= 0.00001 \text{ g.L}^{-1}$ (Convert g $\rightarrow$ mol)
 $= 0.00001/207.2$
 $= 4.8 \times 10^{-8} \text{ M}$

B Convert to number of g per 100mL to determine the concentration in %w/v

$$10 \mu\text{g.L}^{-1} \text{ (divide by 10 to determine } \mu\text{g}/100\text{mL)} = 1 \mu\text{g}/100\text{mL} \text{ (convert } \mu\text{g} \rightarrow \text{g})$$

$$= 1 \times 10^{-6} \text{ g}/100\text{mL}$$

$$= 1 \times 10^{-6} \% \text{w/v}$$

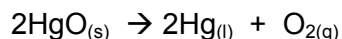
C Convert $\mu\text{g} \rightarrow \text{mg}$

$$1000 \mu\text{g} = 1\text{mg} \text{ (therefore divide by 1000 to convert } \mu\text{g} \rightarrow \text{mg)}$$

$$10 \mu\text{g.L}^{-1} = 0.010 \text{ mg/L}$$

D ppm are equivalent to mg/L therefore $10 \mu\text{g.L}^{-1} = 0.010 \text{ ppm}$ not 0.10 ppm

QUESTION 4 Answer is A



$$m(\text{HgO})_{\text{reacted}} = 20/100 \times 40.0 = 8.00\text{g}$$

$$n(\text{HgO})_{\text{reacted}} = 8/(200.6 + 16) = 0.0369 \text{ mol}$$

$$n(\text{O}_2) = 0.0369/2 = 0.0185 \text{ mol}$$

$$p(\text{O}_2) = \frac{0.0185 \times 8.31 \times (25 + 273)}{0.500}$$

$$= 91.5 \text{ kPa}$$

$$= 91.5/101.325$$

$$= 0.903 \text{ atm}$$

QUESTION 5 Answer is D

A deliquescent substance, such as sodium hydroxide, absorbs moisture from the atmosphere. This means that when a certain mass of the compound is measured, you end up with less of the substance than you think you have. If this mass is then used to make a primary standard, the solution will be less concentrated than it should be. A basic standard solution that has a lower concentration than expected will always make the acid it is reacting with seem more concentrated.

Acid in the burette: If you add the acid to a set volume of the base, less volume of acid will be needed to neutralise the base making it seem concentrated

$C_{\text{acid}} = \frac{n}{V}$ if V is smaller than it should be then $[\text{acid}]$ will be larger than it should be.

Base in the burette: The volume of base needed to neutralise a set volume of acid will be larger than expected which indicates that the acid is concentrated.

$V(\text{base})\uparrow \quad n(\text{base})\uparrow \quad n(\text{acid})\uparrow \quad c(\text{acid})\uparrow$ since $C_{\text{acid}} = \frac{n\uparrow}{V(\text{constant})}$

QUESTION 6 Answer is C

It is not possible to determine which acid or base were used in this titration, only that both are strong species. Therefore, the answer cannot be B or D.

QUESTION 7 Answer is B**QUESTION 8** Answer is D**QUESTION 9** Answer is C**QUESTION 10** Answer is C

If the mass used for the sample was smaller than it should be then the mass of the NaCl will form a higher percentage of the total mass i.e. the calculated percentage will be higher.

QUESTION 11 Answer is B

$$\begin{aligned} c(\text{Ca}^{2+}) &= 0.021 \text{ \%w/v} \\ c(\text{Ca}^{2+})_{\text{diluted}} &= 0.021/2 \\ &= 0.0105 \text{ \%w/v} \\ &= 0.0105\text{g}/100\text{ml} \\ &= 0.105\text{g/L} \\ &= 105 \text{ mg/L} \end{aligned}$$

Abs = 0.22 when concentration = 105 mg/L

QUESTION 12 Answer is A**QUESTION 13** Answer is C

The mass of the ester is less than the mass of the two reactants it was made from.

$$m(\text{ester}) = m(\text{acid}) + m(\text{carboxylic acid}) - m(\text{H}_2\text{O})$$

Therefore the % C in the ester is higher than the %C in the reactants

QUESTION 14 Answer is B

QUESTION 15 Answer is A

$$M(\text{peptide}) = \sum M(\text{amino acids}) - m(\text{H}_2\text{O})_{\text{lost}}$$

To link twelve A.A.'s together, 11 molecules of water would be lost

$$\begin{aligned} M(\text{peptide}) &= ((4 \times 76.06) + (2 \times 89.09) + (6 \times 117.15)) - (11 \times 18) \\ &= 987.3 \text{ g mol}^{-1} \end{aligned}$$

QUESTION 16 Answer is A

The tertiary structure is maintained by interactions between Z groups.

QUESTION 17 Answer is A

Even though biofuels undergo combustion and release CO_2 , they also consume CO_2 during their growth. Therefore they do not increase the amount of CO_2 in the atmosphere (they are carbon neutral fuels).

QUESTION 18 Answer is D

QUESTION 19 Answer is D

Stearic acid is the only saturated acid in the list ($\text{C}_n\text{O}_{2n}\text{O}_2$). It will not react with Br_2 since it has no double bonds. It will have the highest melting point due to the regular structure of the hydrocarbon chain which allows for stronger dispersion forces to exist between its molecules compared to the other two acids.

QUESTION 20 Answer is A

SECTION B – SHORT ANSWER QUESTIONS

QUESTION 1

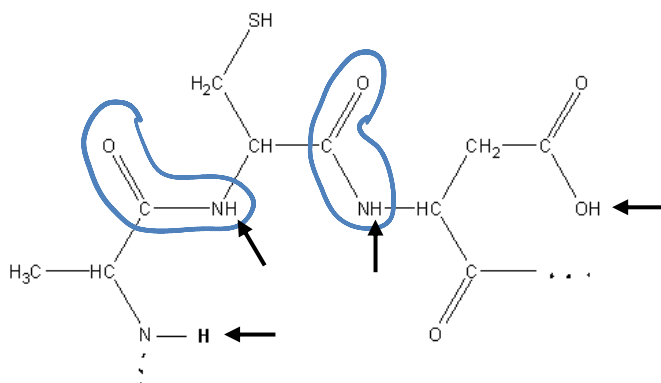
- a. (i) At m/z 122 and 124.
- (ii) The peak at m/z 124 represents the fragment $CH_3CH_2CH_2Br^+$ based on the ^{81}Br isotope, whereas the peak at m/z 122 is based on the ^{79}Br isotope.
- b. (i) $CH_3CH_2CH_2^+$ (must be positively charged).
- (ii) There are no combinations involving ^{12}C , 1H , ^{16}O or the two isotopes of Br that could produce a fragment with m/z 44. Therefore, the fragment is likely to be based on an isotopic variation of these atoms. Eg. ^{13}C or 2H .

Possible answers include: $CH_3CH_2CH_2^+$ with a ^{13}C atom.

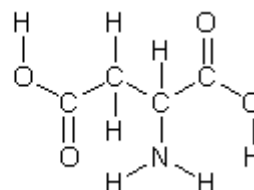
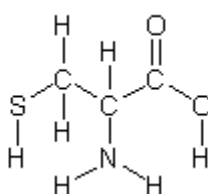
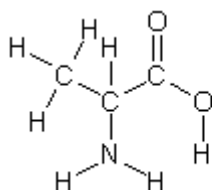
$CH_3CH_2CH_2^+$ with a 2H atom.

QUESTION 2

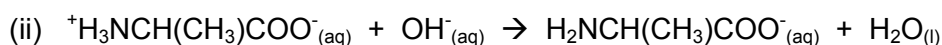
- a. (i) Peptide link (circled in blue).



- (ii) Any hydrogen indicated by an arrow on the above diagram.
- b. (i) The three amino acids making up this peptide chain are:



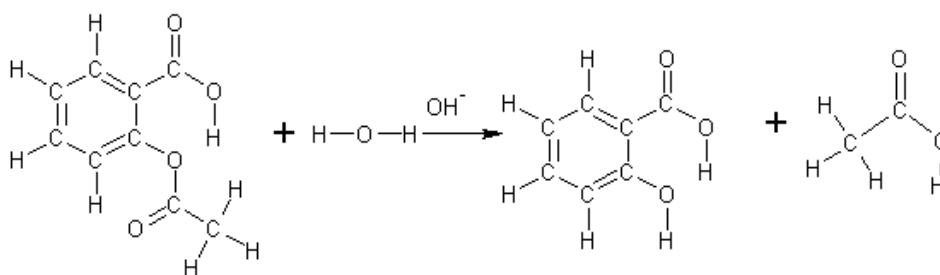
The amino acid with the largest molecular weight is the third one.



- c. (i) α -amino acids or essential amino acids.
 (ii) CO_2 H_2O $\text{C}(\text{NH}_2)_2\text{O}$
- d. Some diseases cause elevated levels of certain proteins to be produced. Testing the levels of these proteins enables diseases to be diagnosed at an early stage. For example, prostate cancer involves the prostate gland releasing a prostate-specific antigen (PSA) into the blood. With cancer or inflammation of the prostate, the level of PSA in the blood is elevated and this can be used to monitor or diagnose disease.

QUESTION 3

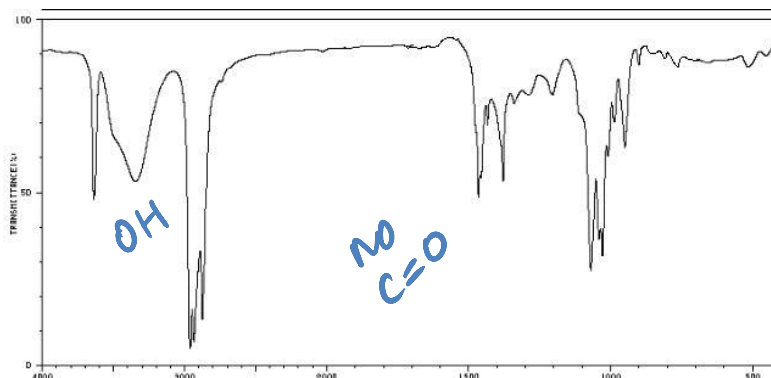
- a. Direct titrations involving weak acids or bases do not usually result in a sharp end point. If a sharp end point cannot be achieved, an accurate concentration for the unknown solution cannot be determined. In cases such as these, a back titration is used.
- b. (i) $n(\text{HCl}) = 0.01375 \times 0.1056 = 1.452 \times 10^{-3} \text{ mol}$
- (ii) $n(\text{NaOH})_{\text{inxs } 25.00\text{ml}} = 1.452 \times 10^{-3} \text{ mol}$
 $n(\text{NaOH})_{\text{inxs } 50.00\text{ml}} = 2 \times 1.452 \times 10^{-3} \text{ mol}$
 $= 2.904 \times 10^{-3} \text{ mol}$
- (iii) $n(\text{NaOH})_{\text{initially}} = 0.02000 \times 0.2520 = 5.040 \times 10^{-3} \text{ mol}$
 $n(\text{NaOH})_{\text{left over}} = 5.040 \times 10^{-3} - 2.904 \times 10^{-3} = 2.136 \times 10^{-3} \text{ mol}$
- c. $n(\text{asprin}) = 2.136 \times 10^{-3} / 2 = 1.068 \times 10^{-3} \text{ mol}$
 $m(\text{asprin}) = 1.068 \times 10^{-3} \times 180 = 0.19224 \text{ g}$
 $\% \text{ purity} = 0.19224 / 0.2000 \times 100 = 96.12\%$
- d. (i)



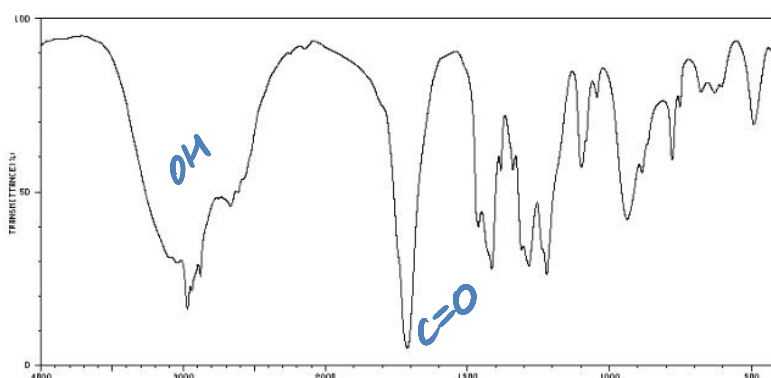
- (ii) Aspirin would display two peaks at approximately 1700cm^{-1} due to the two carbonyl groups in its structure whereas salicylic acid would only have one. Also salicylic acid could have two peaks at approximately 3300cm^{-1} (for the lone hydroxy group) and 3000cm^{-1} (for the hydroxy group that is part of the carboxylic acid). These peaks may merge together to show one strong peak at around $3000 - 3300 \text{ cm}^{-1}$.

QUESTION 4

a.



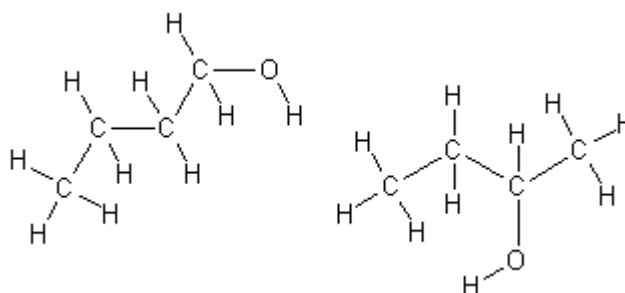
Sample W



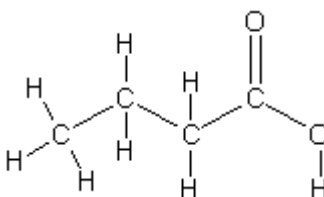
Sample X

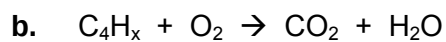
Both structures X and W contain at least one oxygen atom, indicated by OH and C=O troughs in the above spectra. Therefore, X and W must be $C_4H_{10}O$ and $C_4H_8O_2$.

Spectrum W has a trough at approximately 3200 cm^{-1} which corresponds to an OH group but has no trough for a C=O. Therefore its formula is $C_4H_{10}O$. Since the structure is a straight chain, the possible structures include:



Spectrum X shows a trough in the region characteristic of an OH and C=O group meaning that it must represent the carboxylic acid (not an ester) with the formula $C_4H_8O_2$. Since it is also a straight chain molecule, its structure must be:





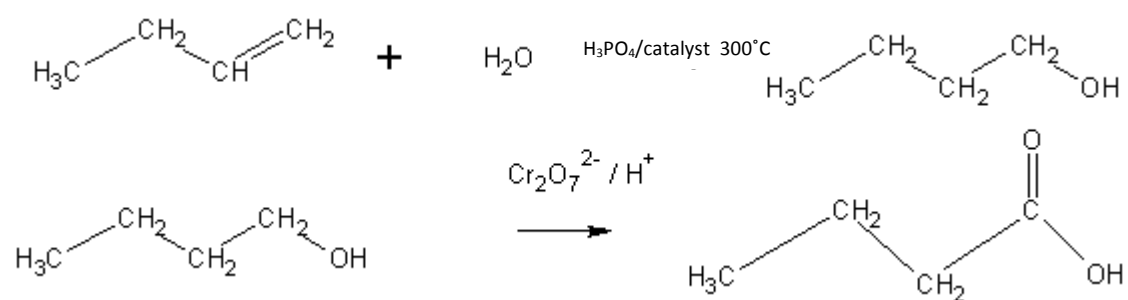
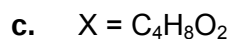
$$n(\text{CO}_2) = 0.7857/44 = 0.01786 \text{ mol}$$

$$n(\text{C}) = 0.01786 \text{ mol}$$

$$\begin{aligned} n(\text{compound Y}) &= 0.01786/4 \\ &= 0.004464 \text{ mol} \end{aligned}$$

$$\begin{aligned} M(\text{compound Y}) &= 0.25/0.004464 \\ &= 56 \text{ g/mol} \end{aligned}$$

Since $4 \times M(\text{C}) + 8 \times M(\text{H}) = 48 + 8 = 56$ then molecular formula of Y is C_4H_8 .



QUESTION 5

a. 400 nm

b. 600 sec

c. (i) 1.0mmol/l

$$\begin{aligned} \text{(ii) } n(4\text{-nitrophenoxide}) &= c \times V \\ &= 1.00 \times 10^{-3} \times 0.0025 \\ &= 2.50 \times 10^{-6} \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{(iii) } n(4\text{-nitrophenylethanoate})_{\text{initially added}} &= n(4\text{-nitrophenoxide})_{\text{produced in reaction}} \\ &= 2.50 \times 10^{-6} \text{ mol} \end{aligned}$$

$$\begin{aligned} c(4\text{-nitrophenylethanoate}) &= n/V \\ &= 2.50 \times 10^{-6} / 0.00025 \\ &= 0.0100 \text{ M} \end{aligned}$$

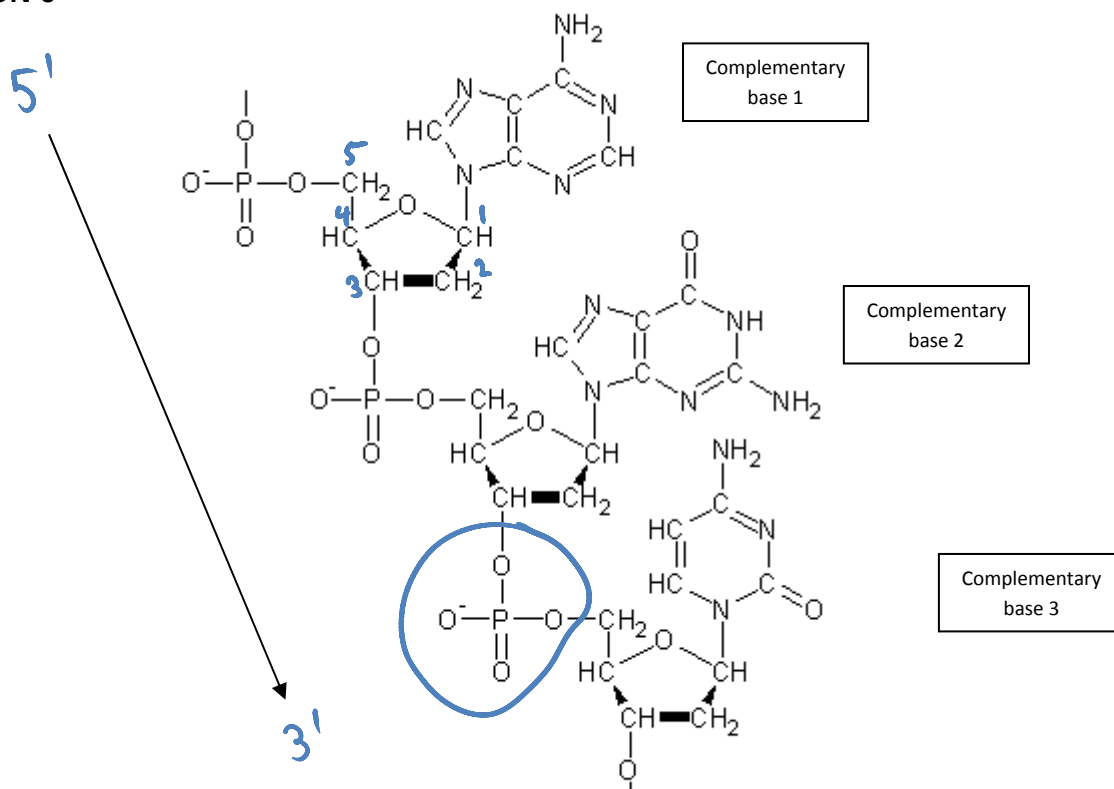
$$\begin{aligned} n(\text{NaOH}) &= 2 \times n(4\text{-nitrophenylethanoate}) = 2 \times 2.50 \times 10^{-6} \\ &= 5.00 \times 10^{-6} \text{ mol} \end{aligned}$$

$$\begin{aligned} c(\text{NaOH}) &= n/V \\ &= 5.00 \times 10^{-6} / 0.00225 \\ &= 0.00222 \text{ M} \end{aligned}$$

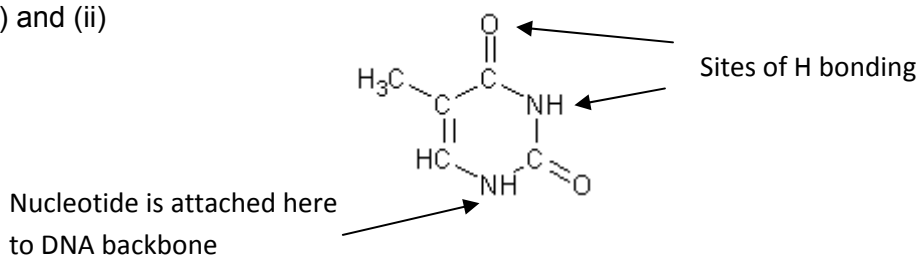
$$\begin{aligned} V &= 2.5 \text{ ml} - 0.25 \\ &= 2.25 \text{ ml} \\ &= 0.00225 \text{ L} \end{aligned}$$

(iv) Light is shone through a reference cell which contains the solvent used in the sample cell so that any absorbance due to the solvent and cuvette is disregarded by the spectrometer. If this did not occur, the absorbance reading would be higher than it should be and so would the calculated concentration of the sample.

QUESTION 6



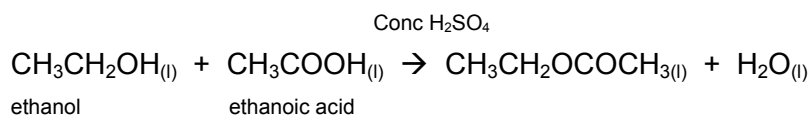
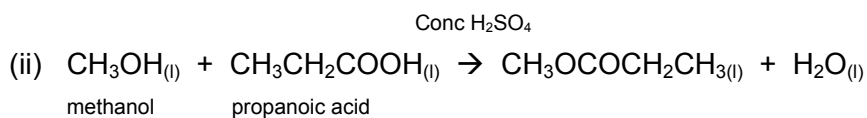
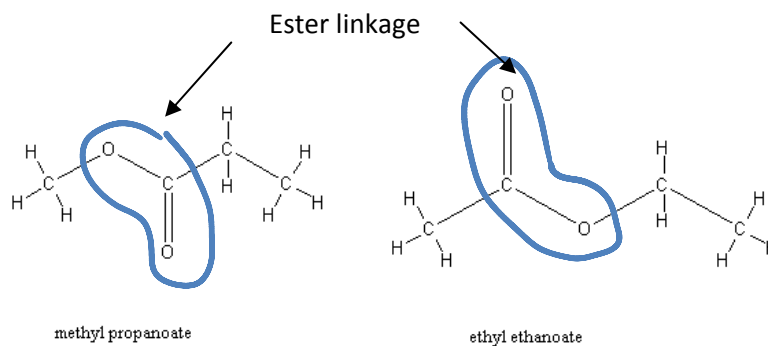
- a. (i) Phosphodiester link (circled above).
- (ii) 19 molecules of water would be required to hydrolyse the strand into individual nucleotide units. 2 molecules of water would be required to hydrolyse each nucleotide to its phosphate group, deoxyribose sugar and base i.e. 40 molecules of water. Total is 59 molecules of water.
- (iii) Complementary Base 1: Thymine
Complementary Base 2: Cytosine
(Complementary Base 3: Guanine)
- b. As shown above.
- c. In complementary strands of DNA, G always pairs with C and A always pairs with T. Therefore the ratio for these pairs is one to one. G does not pair with T and therefore the ratio of these two nucleotides is determined by the nucleotide sequence of the DNA strand. The nucleotide sequence determines the characteristics of an organism. Therefore no two organisms will have the same nucleotide sequence, resulting in the different G/T ratios.
- d. (i) and (ii)



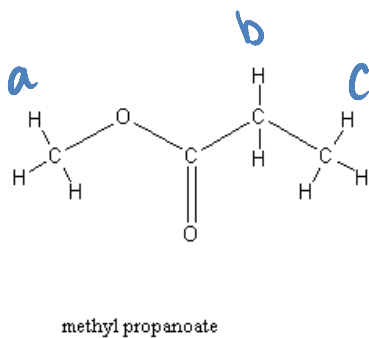
QUESTION 7

- a. Due to the different arrangement of atoms (changes in arrangement lead to changes in properties).

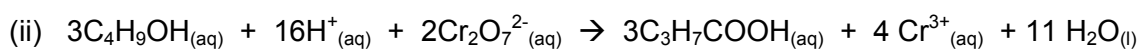
- b. (i)



- c.



- d. (i) GLC

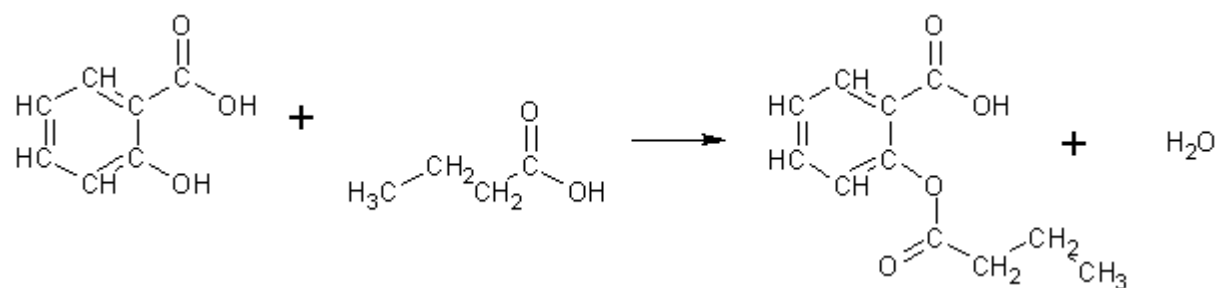


QUESTION 8

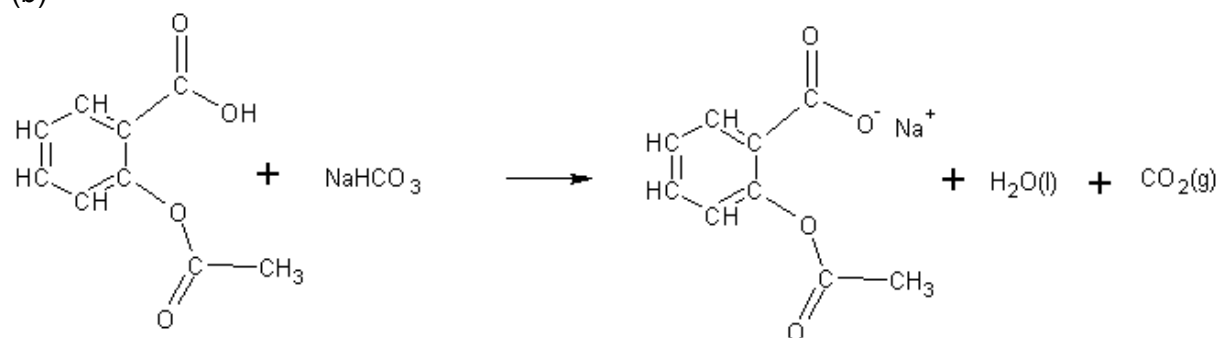
- a. R_f values are a measure of the distance travelled by each component of a mixture up the paper or TLC plate from the origin compared to how far the solvent front has moved from the origin. Components that adsorb more strongly to the stationary phase and spend less time dissolved in the solvent will have small R_f values. R_t refers to the time taken for components of a mixture to elute out of a chromatography column. Components that adsorb more strongly to the stationary phase and spend less time dissolved in the solvent will have larger R_t values. R_f and R_t values can be used to identify components by comparing them to the values of known compounds determined under identical conditions.
- b. The chemical shift of a peak in ^1H NMR is determined by the amount of magnetic energy a particular hydrogen environment needs to absorb in order to reach resonance. The less magnetic energy needed for resonance, the higher the chemical shift. The amount of energy needed is reduced if a hydrogen environment has been deshielded (electrons are drawn away from the region). This occurs when a hydrogen environment is close to an electronegative element such as oxygen. Therefore $\text{O}-\text{CH}_3$ is more deshielded than $\text{R}-\text{CH}_3$ and has the larger chemical shift.
- c. In AAS, a specific wavelength of light is used in the analysis so that absorbance is due only to the component of interest. This is achieved by matching the type of lamp used to the metal being analysed. In colorimetry, a filter is used to select the light used in the analysis. This results in a range of wavelengths entering the sample and hence there is more chance that more than one component of the mixture will absorb this radiation. This would lead to a higher absorbance reading and a larger calculated value for the concentration of the sample.
- d. Alkenes are more volatile than the corresponding alkane due to weaker dispersion forces between the molecules. This occurs due to the irregular shape of alkenes around the site of the double bond. This irregularity prevents alkene molecules from getting close to one another and therefore the dispersion forces cannot hold the molecules together as strongly as in alkanes. Alkanes have regular structures that fit closely together allowing for stronger dispersion forces to exist between the molecules. Since the most volatile components exit the gas liquid chromatography column first, alkenes have a shorter R_t than the corresponding alkane.

QUESTION 9

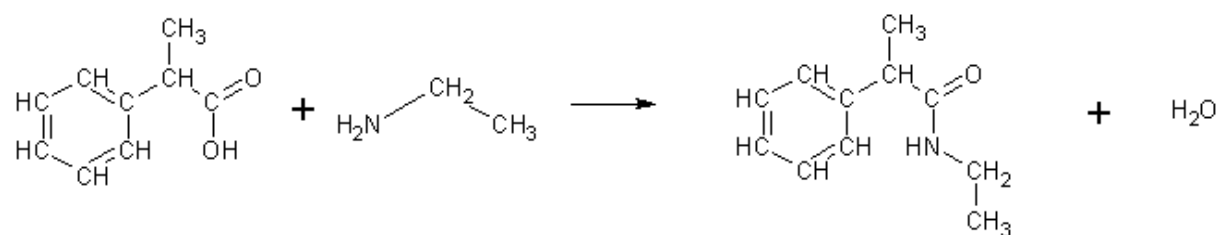
(a)



(b)



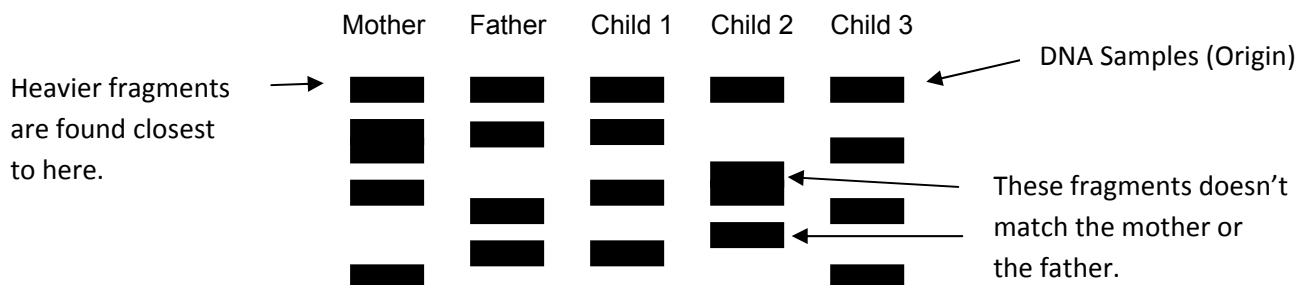
(c)



BONUS QUESTIONS

QUESTION 1

a. Child 2.



- b. Fragments are separated via electrophoresis. A solution of fragments is placed into wells cut into slabs of gel that are made from an electrolyte. The ends of the gel are connected to the positive and negative terminals of a power source and an electric current applied. Since DNA fragments are negatively charged, they are applied at the negative terminal of the gel and migrate under the influence of the electric current towards the positive terminal. The smaller ions move faster and further than the larger ones and hence the fragments are separated from one another.
- c. See diagram above.

QUESTION 2

- a. The peak with the highest m/z ratio represents the parent ion for the molecule. Therefore the peak at 88 indicates that the molecule has a molecular mass of 88 g/mol.

To determine the molecular formula, divide the molecular mass by the mass of the empirical formula:

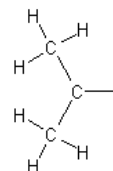
$$88/44 = 2$$

Therefore the molecular formula is $C_4H_8O_2$.

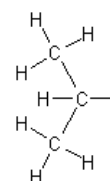
- b. (i) Carbonyl $C=O$
(ii) Hydroxy $-OH$
- c. (i) 3 peaks on the ^{13}C NMR spectrum represents 3 different carbon environments.
(ii) 3 peaks on the 1H NMR spectrum represents 3 different hydrogen environments.
- d. The IR spectrum indicates that the molecule is a carboxylic acid.

1H NMR spectrum:

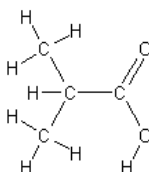
Shift of peak at approx 1 ppm is due to $R-CH_3$. There 6 hydrogen's contributing to this group which indicates two methyl groups attached to a carbon chain. The peak is split into a doublet indicating that the adjacent carbon has 1 hydrogen attached to it.



The peak at approx 2.5ppm is due to one hydrogen and is split into a septet indicating that the adjacent atoms have a total of 6 hydrogen's attached (i.e. the carbon that this hydrogen is attached to is adjacent to the two methyl groups mentioned above).

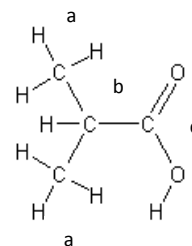
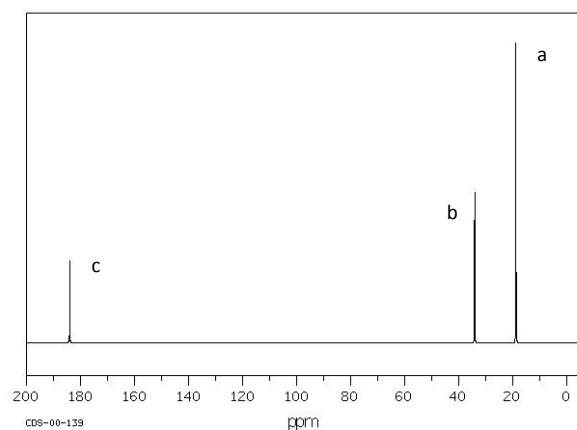


The peak at 2.5 ppm is also shifted slightly to the left indicating that this H is also adjacent to a carbonyl group which in turn is part of the carboxy group. Therefore, the structure is:



The peak at 12 ppm corresponds to the H in the OH group.

This structure is consistent with the ^{13}C NMR spectrum:



QUESTION 3

- a. (i) 4-chloropentanoic acid
(ii) 4,5-dimethyl-2-hexanol

b.

