CHEMISTRY

Units 3 & 4 – Written examination

2013 Trial Examination

SOLUTIONS

SECTION A : Multiple-choice questions (1 mark each)

Question 1

Answer: D

Explanation:

$n(CaCO_3) = \frac{m}{M} = \frac{400}{100} = 4mol$

The question refers to oxygen atoms. The $n(O) = 3n(CaCO_3) = 3 \times 4$
The question asks for the 'number' not the 'number of mole', therefore the above answer needs to be multiplied by 6.02×10^{23}
Answer is therefore $3 \times 4 \times 6.02 \times 10^{23}$

Question 2

Answer: B

Explanation:

$n(S) = \frac{16}{32} = 0.5\ mol$
$n(X) = n(S) = 0.5\ mol$

If 0.5 mol of X has a mass of 20 g, then 1 mole will have a mass of 40 g. This matches calcium. CaS makes sense from an electrovalence point of view.

Question 3

Answer: B

Explanation:

Equation: $MgCl_2(aq) + 2AgNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + 2AgCl(s)$
Silver nitrate is therefore the limiting reagent. The $n(AgCl) = n(AgNO_3) = 0.250$ mol

Question 4

Answer: D

Explanation:

Equation: $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$
Since all reactants are gases, and the conditions are constant, there is no need to convert to mole.
The coefficients in the equation show that 8.0 L of methanol forms 8.0 L of carbon dioxide and 16 L of steam

Question 5

Answer: D

Explanation:

If pH = 13, therefore $[H_3O^+] = 10^{-13}$, therefore $[OH^-] = 10^{-1}$
The solution that could have $[OH^-] = 10^{-1}$ is 0.05 $Mg(OH)_2$.
Remember to take account of the $(OH)_2$ in $Mg(OH)_2$

Question 6

Answer: C

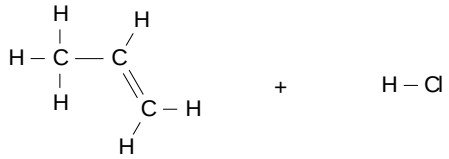
Explanation:

n(methyl red) = $c \times V = 0.01 \times 0.015 = 0.00015$ *mol*
n(NaOH) = n(methyl red) = 0.00015 *mol*
c(NaOH) = $n/V = 0.00015/0.02 = 0.0075$ M

Question 7

Answer: C

Explanation:



The chlorine atom can be placed on either side of the double bond, making 1-chloropropane or 2-chloropropane

Question 8

Answer: B

Explanation:

The loss of the double bond in propene is addition and the loss of the Cl atom in the second molecule is substitution

Question 9

Answer: A

Explanation:

I must be correct. With 5 peaks there are at least 5 substances.
II is incorrect as there might be two substances overlapping to give one of the peaks.
III is incorrect. The sensitivity of each substance cannot be assumed to be equal. It is also the area under the peak, not the height of the peak that is used.
IV is incorrect. The polarity and boiling point of the molecule can be more significant than mass

Question 10

Answer: A

Explanation:

The phenylamine needs to react with ethanoic acid to form the necessary amide bond in acetaminophen. This is a condensation reaction, also releasing water

Question 11

Answer: D

Explanation:

NH_2 is an amine; Cl obviously chloro or halo; CO- NH- is amide; C—O –C is ether

Question 12

Answer: A

Explanation:

Addition polymerisation occurs over the double bond. This leaves – CH_2 – CH_3 as a branch on every second carbon atom in the chain.

Question 13

Answer: C

Explanation:

Water is a polar solvent. It dissolves other polar molecules. The polar O—H functional group on serine will make it more soluble than the other amino acids.

Question 14

Answer: A
Explanation:

The molecular formula can be established to be $C_{17}H_{31}COOH$ purely by counting up the occurrence of each atom in the sketch. This matches linoleic acid in the Data book. The presence of two double bonds, also suggests that if it is C_{17} then the number of hydrogen atoms will be $H_{31.}$

Question 15

Answer: B

Explanation:

Cytosine pairs with guanine. The percentage of both of these will be 22 x 2 = 44%. This leaves adenine and thymine to account for 56%. Half of 56% is 28%.

Question 16

Answer: A

Explanation:

Citric acid is a triprotic acid. Its ability to release each of the three protons differs, hence it has three different K_a values.

Question 17

Answer: B

Explanation:

The reaction is endothermic, therefore high temperature favours a high yield. There are 2 reactant molecules and 3 product molecules, so a low pressure will also favour a high yield. This makes B the correct answer.

Question 18

Answer: C

Explanation:

The answer to this question is dictated by the very small value of K. Since K is so small, the %products will be low and the %reactants will be high. Answer C offers this possibility.

Question 19

Answer: B

Explanation:

$CH_3OH \Leftrightarrow 2H_2(g) + CO(g)$ is the reverse of the first reaction and it is also doubled. Therefore K is the reciprocal and it is squared $(1/K^2) = 1 / 2.4^2 = 1/5.6 = 0.174$

Question 20

Answer: D

Explanation:

Carbon dioxide gas is evolved during the reaction so the mass of the flask drops. It gradually plateaus as the reaction goes to completion. B is incorrect because the pH will be rising as the reaction proceeds. A is incorrect as the mass of the gas evolved increases with time.

Question 21

Answer: A

Explanation:

0.005 M LiOH is an alkaline solution with pH over 11. From the Data book, the only indicator that will be red at this pH is phenolphthalein.

Question 22

Answer: C

Explanation:

To obtain this equation, $2Cu^{+}(aq) \rightarrow Cu(s) + Cu^{2+}(aq)$, the first equation needs to be reversed then doubled. It is then added to the second equation i.e.

$2Cu^{+}(aq) \rightarrow 2Cu(s)$ $\Delta H = -602 \times 2 = -1204$

$Cu(s) \rightarrow Cu^{2+}(aq)$ $\Delta H = +795$

Total $\Delta H = -409$ kJ mol^{-1}

Question 23

Answer: B

Explanation:

Question requires trial and error, of multiplying 49.6 by the molar mass of each fuel until one result matches that of the Data book for that fuel.

For butane, C_4H_{10}, the molar mass is 58 g mol^{-1}. Energy = 49.6 x 58 = 2877 kJ.

This matches the butane value

Question 24

Answer: C

Explanation:

The definition of carbon neutral is that a process has no net emissions. It either uses as much carbon dioxide as produced or involves purchase of carbon credits

Question 25

Answer: D

Explanation:

$2H^+ + 2e \rightarrow H_2$
$Mg^{2+} + 2e \rightarrow Mg$
From the electrochemical series, Mg will react with H^+. H^+ reacting is reduction making it the oxidant. Reduction occurs at the cathode and the cathode is negative. Alternative D is consistent with this

Question 26

Answer: A

Explanation:

In a galvanic cell, the strongest oxidant reacts with the weakest reductant. The A^{2+} is the strongest oxidant. Since it is reduced, it is the cathode and the cathode is positive.

Question 27

Answer: C

Explanation:

$Li/Al \rightarrow Al + Li^+ + e$
$MnO_2 + Li^+ + e \rightarrow LiMnO_2$
The overall equation comes from adding these two half equations. Aluminium can be ignored as it is a spectator. The electrons cancel and the Li^+ ions cancel.
This gives $Li + MnO_2 \rightarrow LiMnO_2$

Question 28

Answer: A

Explanation:

In MnO_2, the oxidation state of the Mn is +4 to balance the 2 oxygen atoms.
In $LiMnO_2$, the manganese is now +3 as the Li^+ and the Mn balance the two oxygen atoms.

Question 29

Answer: B

Explanation:

The two relevant half equations are;
$Cl_2(g) + 2e \rightarrow 2Cl^-(aq)$
$2H_2O(l) + 2e \rightarrow H_2(g) + 2OH^-(aq)$
(Due to the concentration of the NaCl being high, the O_2 half equation does not happen.)
The water and the Cl^- react together;
$2H_2O(l) + 2Cl^-(aq) \rightarrow H_2(g) + 2OH^-(aq) + Cl_2(g)$
The products are hydrogen, chlorine and NaOH

Question 30

Answer: C

Explanation:

$Q = It = 4 \times 400 \times 60 = 96500$ C

$n(e) = \frac{96500}{96500} = 1.0\ mol$

Trial and error on each metal to see which one matches. 1 mole of lithium has a mass of 6.9, not 9g. In the case of aluminium, 1.0 mole of electrons will give 1/3 mole of aluminium as it is Al^{3+}. 1/3 mole has a mass of approximately 9 g, making it the correct answer.

SECTION B : Short-answer questions

Question 1

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

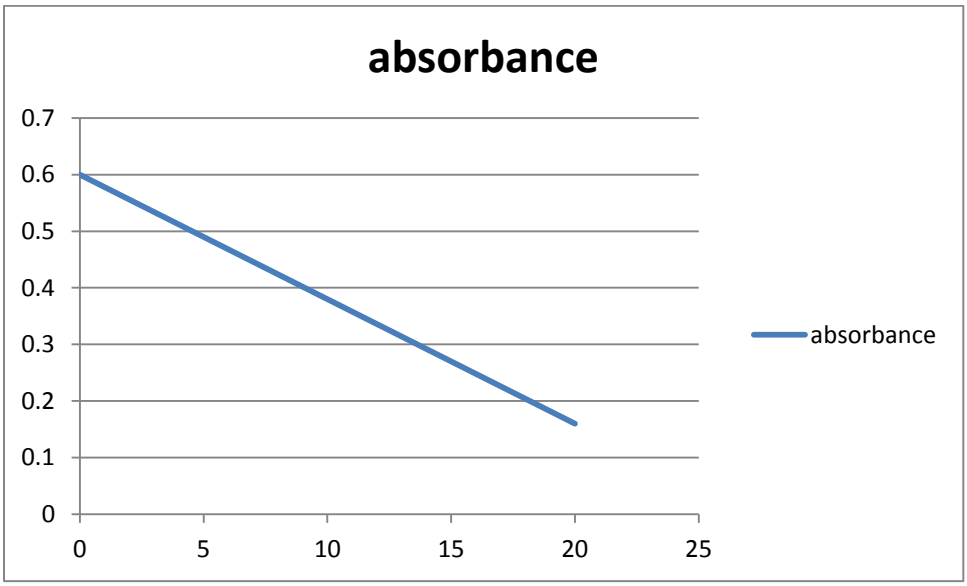
a. i. $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ *

ii. MnO_4^- = (x + 4 x-2) = -1 => +7 *

iii. $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

1 + 1 + 1 = 3 marks

b. i. Use the axes provided to graph the values in the table.



*

ii. The intensity readings are dropping as the reaction proceeds because the amount of MnO_4^- is dropping. It is the MnO_4^- that is causing the pink colour. As the product forms, less pink reactant is present. *

iii. 27.3 mL, probably read off graph as 27 *

iv. $n(KMnO_4^-) = c \times V = 0.1 \times 0.03 = 0.003$ mol *

$n(Fe^{2+}) = 5\ n(KMnO_4^-) = 5 \times 0.003 = 0.015$ mol *
$c(Fe^{2+}) = n/V = 0.015/0.0273 = 0.55$ M*

1 + 1 + 1 + 3 = 6 marks

Question 2

a. $m(H) = 2 - 1.091 - 0.727 = 0.182$ g *

empirical formula = $\frac{1.091}{12} : \frac{0.727}{16} : \frac{0.182}{1} = 0.0909 : 0.0454 : 0.182$ = 2:1:4 * = C_2OH_4 *

3 marks

b. **i**. What is the mass of the parent molecular ion? 88 *

ii. empirical formula is 44 if it is C_2OH_4
If molar mass is 88, then molecular formula is double empirical formula, $C_4H_8O_2$ *

iii. peak - at 15 is CH_3^+ *
- at 29? $CH_3CH_2^+$ *

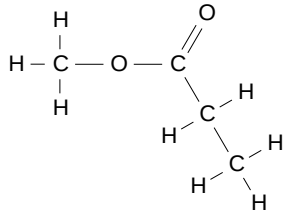
1 + 1 + 2 = 4 marks

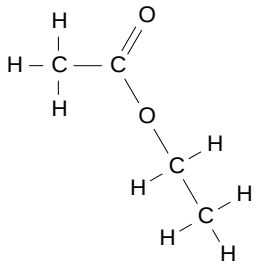
c. **i**. There is no broad peak around 3200 cm^{-1} so there is no –OH bond characteristic of an alcohol *

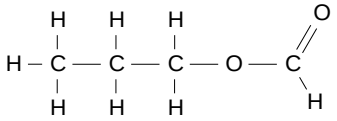
ii. The C = O bond will be the second peak from the left around 1700 cm^{-1} *

1 + 1 = 2 marks

d.





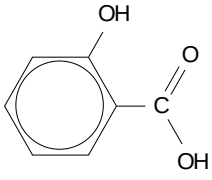


methyl propanoate* ethyl ethanoate * propyl methanoate*

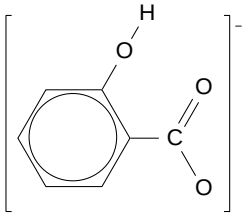
3 marks

Question 3

a. **i**. Show the reaction of salicylic acid with water. *

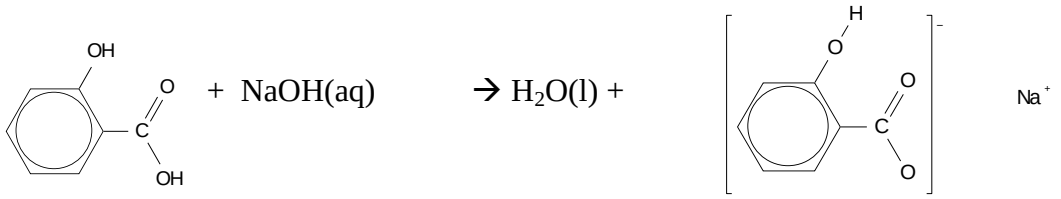


+ $H_2O(l) \Leftrightarrow H_3O^+(aq)$ +



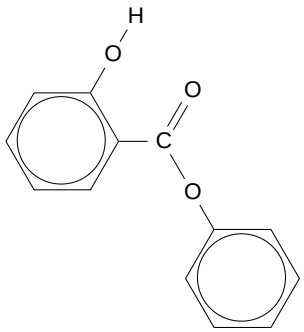
(or shown as $HAS(aq) + H_2O(l) \Leftrightarrow H_3O^+(aq) + AS^-(aq)$)

ii. Write an equation to show the reaction between salicylic acid and sodium hydroxide.



(or shown as a molecular formula or similar format to i) 1 + 1 = 2 marks

b. Draw the structure of phenol salicylate.



*

1 mark

c. **i**. $K_a=\frac{[H3O+][SA-]}{HSA} = \frac{xXx}{0.1} = 1.07 \times 10^{-3}$ * where x = $[H_3O^+]$

$x^2 = 1.07 \times 10^{-4}$ => x = 0.0103M *

pH = -log 0.0103 = 1.99 *

ii. %ionisation = $\frac{[H_3O^+]}{[HAS]} \times 100 = \frac{0.0103}{0.1} \times 100 = 10.3\%$ *

3 + 1 = 4 marks

Question 4

i. Molecule A is not an α-amino acid*. The amine group and the carboxy group must be connected to the same carbon atom for a molecule to be an α-amino acid. *

ii. Two different products depending upon which molecule is placed on the left when the two are joined*

iii.

amino acids			number of possible tripeptides
serine	serine	serine	1
serine	glycine	serine	3
serine	glycine	alanine	6

2 + 1 + 2 = 5 marks

b. **i**. The lipid is made from 3 molecules of linoleic acid + glycerol – 3 molecules of water
= 3 x($C_{17}H_{31}COOH$) + $CH_2OHCHOHCH_2OH$ - 3 x(H_2O) * = $C_{57}H_{98}O_6$ *

ii. $C_{17}H_{31}COOH(l)$ + $25O_2(g)$ → 18 $CO_2(g)$ + 16 $H_2O(g)$ *, 1 mark for phases*

iii. The linoleic acid is converted to an ester by reacting it with methanol or ethanol. Sodium hydroxide is used to aid this reaction*

2 + 2 + 1 = 5 marks

c. Normal diesel is produced from crude oil, therefore it is non renewable. Biodiesel can be made from plant or animal matter that can be replenished. *

1 mark

Question 5

a. In comparing experiment 1 and experiment 2,

i. The final volume of gas evolved will be the same* in experiment 2 as in experiment 1. The calcium is the limiting reagent.*

ii. The initial rate of gas production will be greater in experiment 2 because the acid concentration is higher.*

2 + 1 = 3 marks

b. In comparing experiment 1 and experiment 4,

i. The final volume of gas evolved will be double in experiment 4 . The calcium is still the limiting reagent.*

ii. The initial rate of gas production will be greater in experiment 4 as the surface area is greater.

1 + = 2 marks

c. In comparing experiment 1 and experiment 3,

i. The final volume of gas evolved will be the same

ii. The initial rate of gas production will be greater in experiment where the temperature is higher

1 + 1 = 2 marks

d. i. As the temperature increases, the average kinetic energy increases. Many of the particles will be moving faster. There will be more collisions* and there will be a higher percentage of successful collisions.*

ii. Amylase is an enzyme. Enzymes are heat sensitive. At high temperatures they can be denatured and lose their ability to catalyse a reaction*

2 + 1 = 3 marks

Question 6

a. $K = \frac{[CH3OH]}{[CO][H2]^2} = 3.4^*$ $\Rightarrow 3.4 = \frac{0.32}{x\ x\ 4x^2}$ where [CO] = x and $[H_2] = 2x$

$4x^3 = 0.32/3.4 = 0.0941^* \Rightarrow$ x = 0.29 M*

3 marks

b. **i**. the value of the equilibrium constant: unchanged as temperature constant *

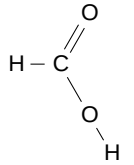
ii. the position of equilibrium: forward reaction favoured to reduce pressure increase*

iii. the amount of carbon monoxide: lower, as reaction went forward *

iv. the concentration of the carbon monoxide: higher due to the volume being halved*

1 + 1 + 1 + 1 = 4 marks

c. **i.** Draw the structure of molecule A



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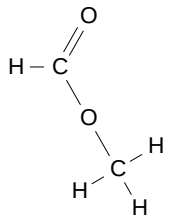
ii. Formula of the reagent required to convert methanol to molecule A? * $H^+/Cr_2O_7^{2-}$

iii. *



iv. Name the catalyst used for the esterification. Sulfuric acid *

1 + 1 + 1 + 1 = 4 marks

Question 7

a. mass of ethanol reacting = 46.82-46.18 = 0.64 g*

n(ethanol) = $\frac{0.64}{46} = 0.0139 mol$ *

energy = 0.0139 x 1368 = 19.0 kJ*

3 marks

b. E = 4.18 x m x ΔT = 19000 = 4.18 x 450 x ΔT*

=> $\Delta T = 10.1\ ^0C$ *

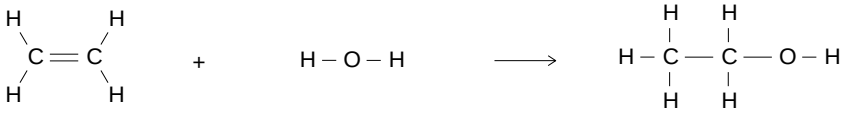
Final temp = 21 + 10.1 = 31.1^0C

2 marks

c. Non renewable

i. Name a non renewable source of ethanol crude oil, petroleum *

ii.



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Another method would be substitution onto chloroethane *

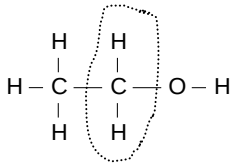
Renewable

iii. Name a renewable source of ethanol : sugar cane, plant matter *

iv. $C_6H_{12}O_6$ (s) → $2CH_3CH_2OH$(aq) + $2CO_2$(g)* fermentation

1 + 1 + 1 + 1 = 4 marks

d.

i. How many different  hydrogen environments does ethanol have? 3 *

ii. The $-CH_2-$ group circled above will be a quartet. It has three neighbouring hydrogen atoms.* Under the n + 1 rule, this means 4 peaks.*

iii. 3.6 from data book *

1 + 2 + 1 = 4 marks
Total 13 marks

Question 8

a. Two reasons from: aluminium is relatively cheap; it is light weight, voltage is high, air is cheap**

2 marks

b. **i**. occurring at the anode $Al(s) + 3OH^-(aq) \rightarrow Al(OH)_3(aq) + 3e^-$ *

ii. occurring at the cathode $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ *

1+ 1 = 2 marks

c. Which electrode will be the positive electrode? O_2 electrode *

1 mark

d. A typical secondary cell is recharged by attaching a power supply to it to reverse the reactions, reforming the original reactants. Here the original material is 'replenished' by a mechanical replacement of the material. Hence it can continue to operate but was not recharged by an external power supply *

1 mark

e. From the half equations, one of the half equations requires both oxygen and water*. These come from the air. The small hole allows air to enter and the cell becomes functional *

2 marks

Total 8 marks

Question 9

a. **i**. Polarity: negative * $CO_3^{2-} + H_2 \rightarrow H_2O + CO_2 + 2e$

Polarity: positive * $CO_2 + ½O_2 + 2e \rightarrow CO_3^{2-}$

ii. Carbonate ions flow towards the anode. *

1 + 1 = 2 marks

b. $2H_2 + O_2 \rightarrow 2H_2O$*

1 mark

c. The cell is carbon neutral – any carbon dioxide produced at one electrode is used up at the other *

1 mark

d. Fuel cells are not rechargeable. They have a continuous supply of reactants, hence don't need to be recharged. *

1 mark

Question 10

a. **i**. $m(Cu) = 54.898 - 54.606 = 0.292$ g *

$n(Cu) = \frac{0.292}{63.5} = 0.0046\ mol$ *

ii.

$n\ (Cl_2) = \frac{PV}{RT} = \frac{150x\ 0.092}{8.31x723} = 0.0023$ mol **

iii. Formula is CuCl since the number of mole of Cl_2 = ½ n(Cu)

2 + 2 + 1 = 5 marks

b. anode: $2Cl^-(l) \rightarrow Cl_2(g) + 2e$ * cathode: $Cu^+(l) + e \rightarrow Cu(l)$ *

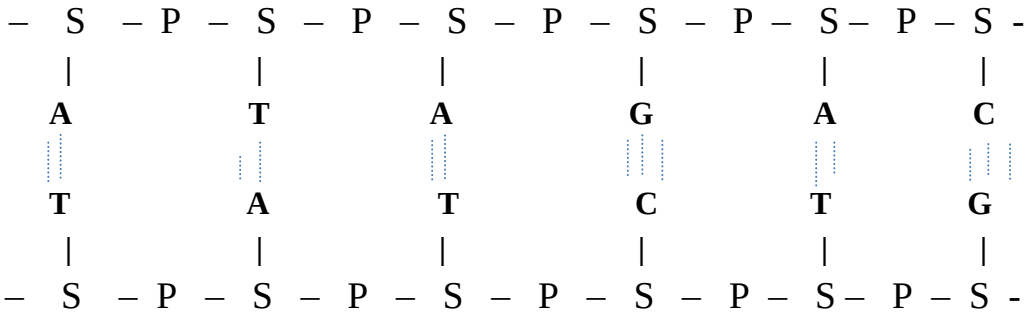
1 + 1 = 2 marks

c. The copper ions are reduced from +2 to + 1. $Cu^{2+} \rightarrow Cu^+$ *

1 mark

Question 11

a.



i. As shown above. **

ii. Hydrogen bonds shown between bases; 2 between each A and T, 3 with C and G *

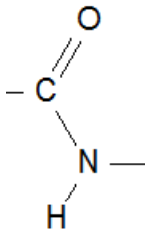
iii. The other strand might have a higher % of C and G base than this strand *

iv. carbon, hydrogen, oxygen, phosphorous, nitrogen *

2 + 1 + 1 + 1 = 5 marks

b. Name the type of biomolecule that might contain the following linkages and name a biomolecule that this linkage is present in

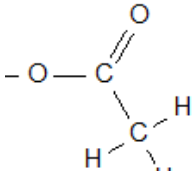
i.



Name of linkage: amide

Linkage present in: protein *

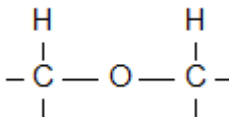
ii.



Name of linkage: ester

Linkage present in: lipid *

iii.



Name of linkage: ether *

Linkage present in: polysaccharides*

1 + 1 + 1 = 3 marks

Total 8 marks