CHEMISTRY

Unit 3 – Written examination 1

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SOLUTIONS

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

Question 1

Answer: D

Explanation:

A partial equation for the reaction is

$2Na_3PO_4 + .. \rightarrow Mg_2P_2O_7 + ..$

Therefore, the $n(P) = 2xn(P_2O_7 \text{ ions}) = n(PO_4^{3-}) = 2x0.25 = 0.5mol$
$n(Na^+) = 3xn(PO_4) = 3 \times 0.5 = 1.50\ mol$

Question 2

Answer: C

Explanation:

The beaker contents are acidic at first, with a pH around 1. The NaOH gradually increases the pH as it is added. The first beaker to change colour will be the one with the lowest pH transition. This is methyl orange.

Question 3

Answer: B

Explanation:

This is a titration between a weak base and a strong acid. A weak base has a pH around 10 to 11, while a strong acid will have a pH around 1 or 0. The graph represents the strong acid being added to the base.

Question 4

Answer: D

Explanation:

Chloromethane has a formula of CH_3Cl. If the chlorine atom is the ^{37}Cl isotope, then the mass of this ion will be (12 + 3 + 37) = 52

Question 5

Answer: A

Explanation:

The precipitate weighed is barium sulfate, $BaSO_4$.

$n(BaSO_4) = \frac{1.5}{233.3} = 0.0064\, mol$

$n(Ba(NO_3)_2) = n(BaSO_4) = 0.0064$ mol

Question 6

Answer: A

Explanation:

The oxygen gas is the scarce reactant: ($n(O_2) = 4/3 \times 0.36 = 0.48$ mol. The Al is in excess)
$n(Al_2O_3) = 2/3 \times 0.36 = 0.24$ mol

Question 7

Answer: A

Explanation:

If H_2SO_4 is acting as an oxidant, it must be reduced. The oxidation number of sulphur in H_2SO_4 is +6. The only alternative that has sulphur with a lower oxidation state is SO_2. The sulphur is +4 in SO_2

Question 8

Answer: B

Explanation:

$$V = \frac{P_2 V_2 T_1}{T_2 P_1} = \frac{4x80x320}{300x4} = 85.3L$$

Question 9

Answer: D

Explanation:

m(N)= 0.56g; m(O) = 2.16 – 0.56 = 1.6g

empirical formula

$$\frac{0.56}{14} : \frac{1.6}{16} = 0.04 : 0.1 = 1 : 2.5 = 2 : 5$$

Question 10

Answer: C

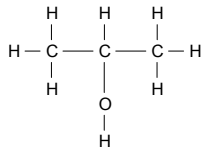
Explanation:

2 mole of ethene will produce 2 mole of ethanol.
The mass of 2 mole of ethanol is 2 x 46 = 92 g

Question 11

Answer: B

Explanation:



2-propanol will have three sets of peaks. The O – H is not split as it is attached to the oxygen atom. The other hydrogen atom on the middle carbon has 6 equal neighbouring hydrogen atoms. Under the n+1 rule, this will lead to a septet (split in 7)

Question 12

Answer: D

Explanation:

The order of boiling points will be, lowest to highest, propanol then hexanol and then octanol. In laboratory distillation the lowest boiling point substance, propanol, will be the first to be distilled. In the industrial process, it will rise further up the column before condensing than the other two liquids. Hexanol is the middle molecule in both processes. Octanol will be the final substance to boil in laboratory distillation and it will not rise as far up the fractionating column as the other two substances.

Question 13

Answer: D

Explanation:

There is no consistent difference between Run 1 and Run 2. Run 2 is not a higher temperature or all retention times would be lower. It is not a lower temperature as all retention times are not greater. It is not a higher flow rate or all retention times would be lower. That leaves D as a possible alternative.

Question 14

Answer: C

Explanation:

The semi-structural formula is $CH_3CHCHCH_2Cl$. There must be a double bond between the middle C atoms. Numbering the molecule should start from the right hand end, making it 1-chloro.

Question 15

Answer: B

Explanation:

Both molecules are alkanols. They are both likely to be soluble in water (option B). Proton NMR will have a different number of peaks for each molecule. The first molecule is not a primary alkanol, so it will not react with $Cr_2O_7^{2}$. The fingerprint region is unique for all molecules.

Question 16

Answer: A

Explanation:

From the Data book, the amino acid is serine. It does however have an extra H atom. This will happen in acid conditions.

Question 17

Answer: A

Explanation:

- CO – O - = ester; -NH – CO - = amide, - NH_2 = amino; - COOH = carboxyl

Question 18

Answer: A

Explanation:

Adding up the atoms gives $C_{17}H_{31}COOH$. This is identified as linoleic acid from the Data book. To save adding up all the hydrogen atoms, you could count up the carbon atoms. There are 18. If saturated, the number of H atoms should be double that or 36. For each double bond, subtract 2 hydrogens. Therefore this molecule has 32 hydrogen atoms making it linoleic acid.

Question 19

Answer: C

Explanation:

Each adenine and thymine has two hydrogen bonds. The cytosine and guanine have three.
Total is 2 + 2 + 2 + 2 + 3 + 3 + 3 =17

Question 20

Answer: B

Explanation:

When the three components combine, two water molecules are released. The mass therefore drops by 2 x 18 = 36. 536 – 36 = 500

SECTION B – Short answer questions
*An * indicates the allocation of 1 mark*

Question 1

a. $2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2CO_3(aq)$ * *(states 1 mark)
(Given the dilute solutions, H_2CO_3 is preferable to CO_2 and H_2O)

2 marks

b. **i**. 15 mL.* Given the scale, 14.5 to 15.5 acceptable

ii. $n(HCl) = c \times V = 0.1 \times 0.015 = 0.0015$ *mol*
$n(Na_2CO_3) = ½\ n(HCl) = ½ \times 0.0015 = 0.00075$ *mol**

$$c(Na_2CO_3) = \frac{0.00075}{0.02} = 0.038\ M*$$

1 + 2 = 3 marks

c. **i**. Phenolphthalein changes at pH 8.3 – 10. The titration would be halted before the equivalence point if phenolphthalein was used. Titre perhaps 13.5 – the exact value given does not matter but the value must be less than the titre of 15 mL. *

ii. $n(HCl) = c \times V = 0.1 \times 0.0135 = 0.00135$ *mol*
$n(Na_2CO_3) = ½\ n(HCl) = ½ \times 0.00135 = 0.000658$ *mol**

$$c(Na_2CO_3) = \frac{0.000685}{0.02} = 0.034\ M*$$

iii. As the difference in concentrations above illustrates, it is a poor choice for strong acid vs weak base.* An indicator with a lower pH transition should be used

1 + 2 + 1 = 4 marks

Question 2

Analytical task and technique chosen	**Reason the chosen method is unlikely to be suitable**
Gravimetric analysis to determine the mass of sodium nitrate in a 100 mL solution of sodium nitrate	$NaNO_3$ consists of Na^+ ions and NO_3^- ions. All compounds of these ions are soluble. Hence, whatever substance is added will not lead to a precipitate*
Separation of a mixture of monosaccharides using GC	Monosaccharides will decompose when heated. Since they cannot be vaporised, they cannot be carried through a GC*
Determination of the concentration of an ethanoic acid solution using a titration against sodium carbonate	Titrations between a weak acid and a weak base are not accurate. The equivalence point and the endpoint are too difficult to discern*
Determination of the concentration of ethanol solutions using infrared spectroscopy	Infrared spectroscopy might identify ethanol but it does not give an indication of the concentration. It is usually considered qualitative*

4 marks

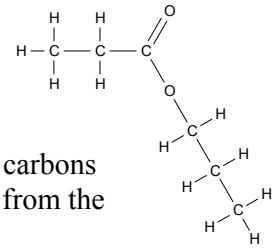
Question 3

a. **i**. oxidation*

ii. ester*

1 + 1 = 2 marks

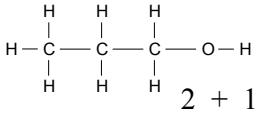
b. **i.** *



propylpropanoate*

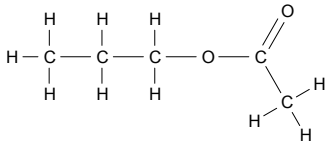
(both alkanol and acid must have 3 carbons each, since they were both formed from the same alkanol)

ii.

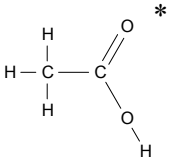


2 + 1 = 3 marks *

c.



* 1 mark

d.  * 1 mark

e. **i**. $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$*

ii. $n(NaOH) = c \; x \; V = 0.1 \text{ x } 0.0086 = 0.00086 \; mol$
$n(CH_3COOH) = n(NaOH) = 0.00086 \; mol$*

$$c(CH_3COOH) = \frac{0.00086}{0.02} = 0.043 \; M*$$

1 + 2 = 3 marks
Total 10 marks

Question 4

a.

Reactor	Contents	no mole
1	20 g of magnesium metal	20/24.3 = 0.823
2	2 L of 0.9 M HCl	2 x 0.9 = 1.8
3	2 L of HCl of pH 1	pH = 1 = 0.1 M; n=2x 0.1 = 0.2

*
The third column of the table shows that reactor 2 has the greatest amount of reactant, hence it will form the most hydrogen*

2 marks

b. $n(Mg) = \frac{2}{24.3} = 0.0823 mol$ $n(HCl) = 0.2 \text{ x } 1.0 = 0.2 \; mol$ *

$n(HCl \text{ reacting}) = n(Mg) \text{ x } 2 = 0.0823 \text{ x } 2 = 0.165 \; mol$
$n(HCl \text{ remaining}) = n(start) - n(reacting) = 0.2 - 0.165 = 0.035 \; mol$*

$$c(HCl) = \frac{n}{V} = \frac{0.035}{0.2} = 0.175M \qquad pH = -\log(0.175) = 0.76*$$

3 marks

c. the substance in the evaporating basin should be $MgCl_2$

$n(MgCl_2) = \frac{0.44}{95.3} = 0.00462mol$ *

$n(H_2) = n(MgCl_2) = 0.00462mol$*

$V = \frac{nRT}{P} = \frac{0.00462x8.31x313}{200} = 0.0600L$ *

3 marks
Total 8 marks

Question 5

A	B	C
CH_2O	$C_3H_7NO_3$	$C_8H_{16}O$

a. **i**. $CH_2O = 30$ $\frac{180}{30} = 6$ => molecular formula = $C_6H_{12}O_6$ *

ii. glucose (or fructose or aldose etc)*

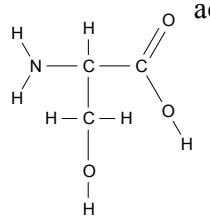
iii. there are several monosaccharides with the same molecular formula as this, but each have different structural formulae.*

1 + 1 + 1 = 3 marks

b.

i. Yes, as most amino acids have one nitrogen atom*

ii.



iii. Serine*

1 + 1 + 1 = 3 marks

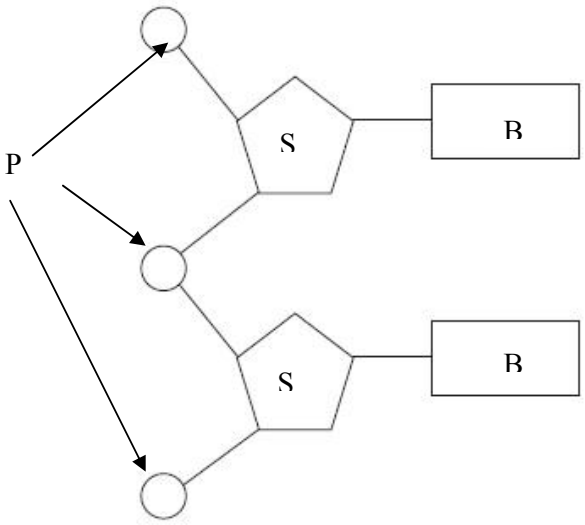
c. Molecule C is a saturated fatty acid.

i. No, as a carboxyl group has two oxygen atoms*

ii. To get 2 oxygen atoms, double the formula $C_{16}H_{32}O_2$ * palmitic acid

1 + 1 = 2 marks
Total 8 marks

Question 6



a. **i**. Label each base molecule on the sketch with the letter B. *

ii. Label each sugar molecule with the letter S. *

iii. Label each phosphate group with the letter P. *

iv. Circle one complete nucleotide (includes one S, one B and one P) *

1 + 1 + 1 + 1 = 4marks

b. cytosine and guanine as both of these have 3 dipoles *

2 marks

c. mass = S + B + P – 36 as two water molecules are released as bonds form between sugar and phosphate and between sugar and base *

1 mark

d. A segment of a DNA molecule is subjected to gel electrophoresis.

i. Positive* as each strand has negative charges from the phosphate

ii. the mass of the strand*. The mass reflects the length of the strand

1 + 1 = 2 marks

Total 9 marks

Question 7

a. **i**. 3 *

ii. 3:2:1 *

iii. CH_3 split into a triplet*, - CH_2 - split into 4*, O – H not split at all *

1 + 1 + 3 = 5 marks

b. **i**. 3300 cm^{-1} alcohol*; 3000 cm^{-1} C – H *

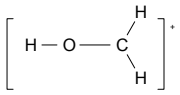
ii. Similarity: both have a broad peak around 3300 cm^{-1} for alcohol.(also C—C, C—H)*

Difference: the fingerprint region for each molecule will not overlap*

2 + 2 = 4 marks

c. **i**. The ethanol molecule might have a ^{13}C atom in it, making its mass 61 *

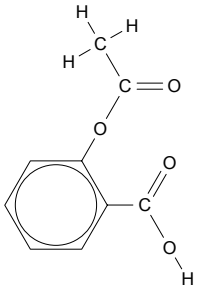
ii. The other fragment will be CH_2OH^+ *



1 + 1 = 2 marks
Total 11 marks

Question 8

An aspirin molecule is shown below.



a. $CH_3COOC_6H_4COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COOC_6H_4COO^-(aq)$*

1 mark

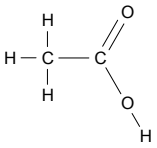
b. **i.** $CH_3COOC_6H_4COOH(aq) + NaOH(aq) \rightarrow CH_3COOC_6H_4COONa(aq) + H_2O(l)$*

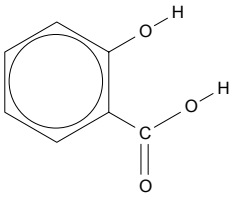
ii. Being an ionic compound, its solubility is greater*

1 + 1 = 2 marks

c.

i.





**

ii. Aspirin is a monoprotic acid. After hydrolysis, each molecule of aspirin has formed two monoprotic acid molecules, one of salicylic acid and one of ethanoic acid. Therefore, twice as much acid is present. *

2 + 1 = 3 marks
Total 6 marks