CHEMISTRY

Units 3&4 – Written examination

2023 Trial Examination

SOLUTIONS

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

Question 1

Answer: D

Explanation:

The second carbon is connected to a CH_3, OH, H and $CH_2CH_2CH_3$ group.

Question 2

Answer: C

Explanation:

Fuel cells convert chemical energy into electrical energy, have a continual supply of reactants, and use porous electrodes, but are not rechargeable.

Question 3

Answer: B

Explanation:

Water is a by-product of the reaction, therefore it is a condensation reaction.

Question 4

Answer: D

Explanation:

The balanced equation for the complete combustion of methanol at SLC is $2CH_3OH\ (l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ and the energy produced is 2×726 kJ mol^{-1}, which is 1452kJ mol^{-1}.

Question 5

Answer: B

Explanation:

The longest carbon chain is 7 carbons, the highest priority group in the amine group and the methyl group is off the 3rd carbon.

Question 6

Answer: B

Explanation:

There are more molecules in the products, so low pressure would favour the forward reaction, and the forward reaction is endothermic, therefore high temperature would favour the forward reaction.

Question 7

Answer: A

Explanation:

Energy in food sample = $1.2 \times 16 + 0.30 \times 17 + 0.50 \times 37 = \ 42.8kJ$
Calibration factor = $\frac{42.8}{15.2} = 2.8$ kJ $^oC^{-1}$

Question 8

Answer: A

Explanation:

Ethanol is oxidised at the anode, therefore $CH_3CH_2OH(aq) + 12OH^-(aq) \rightarrow 2CO_2(g) + 9H_2O(l) + 12\ e^-$

Question 9

Answer: A

Explanation:

Linolenic acid is an omega-6 fatty acid as the first double bond is on the 6^{th} carbon from the end of the molecule.

Question 10

Answer: C

Explanation:

Nickel/zinc = 0.51V, tin(IV)/manganese = 1.33V, silver/nickel = 1.05V and copper/zinc = 1.1V

Question 11

Answer: C

Explanation:

The structural isomers of $C_4H_{11}Cl$ are 1-chloropentane, 2-chloropentane, 3-chloropentane, 1-chloro-2-methylbutane, 1-chloro-3-methylbutane, 2-chloro-3-methylbutane, 2-chloro-2-methylbutane, and 1-chloro-2,2-dimethylpropane.

Question 12

Answer: B

Explanation:

Repeating experiments increases the reliability of the results.

Question 13

Answer: C

Explanation:

Aluminium is in the aqueous state and below water on the electrochemical series, so hydrogen would be produced at the cathode.

Question 14

Answer: D

Explanation:

But-2-ene exists in the cis and trans isomers, whereas ethene, propene and propanol do not form enantiomers.

Question 15

Answer: A

Explanation:

To get the required reaction you must halve the first reaction, double the second reaction and reverse the third reaction. $\Delta H = \frac{1}{2} \times -2999 + 2 \times 394 + 570 = 141.5$ kJ mol^{-1}

Question 16

Answer: C

Explanation:

The IR spectra shows absorbance at 3300-3500, consistent with N-H, and 1630-1680, consistent with C=O (amides).

Question 17

Answer: A

Explanation:

Propanol will travel through the column quickest and butanoic acid will most strongly adsorb to the stationary phase.

Question 18

Answer: D

Explanation:

$C(O_2)$final =0.15M, $C(SO_2)$final=0.3M, $C(SO_3)$final=0.1M
Kc = $\frac{0.3^2 \times 0.15}{0.1^2}$=1.35M

Question 19

Answer: B

Explanation:

Fatty acids with the most double bonds are most likely to undergo oxidative rancidity, therefore arachidonic acid is most likely.

Question 20

Answer: C

Explanation:

The mass increase of each electrolyte would be:

$$\text{Ag} = \frac{300 \times 4.00}{96500} \times \frac{107.9}{1} = 1.34g$$
$$\text{Pb} = \frac{300 \times 4.00}{96500} \times \frac{207.2}{2} = 1.28g$$
$$\text{Hg} = \frac{300 \times 4.00}{96500} \times \frac{200.6}{2} = 1.24g$$
$$\text{Cs} = \frac{300 \times 4.00}{96500} \times \frac{132.9}{1} = 1.65g$$

Question 21

Answer: D

Explanation:

Calibration increases the precision and accuracy of a measurement; repetition determines the reliability and reduces the effect random errors; repeatability involves repeating the experiment under the same conditions. Being able to read the temperature to two decimal places increases the resolution of the measurements.

Question 22

Answer: A

Explanation:

$\frac{100}{24.8} = 4.03$ mol of gas

$\frac{4.03}{2} \times 131.3$ kJ mol^{-1} = 265 kJ

Question 23

Answer: A

Explanation:

$\frac{100}{24.8} = 4.03$ mol of gas
Energy from CO = $\frac{4.03}{2} \times \frac{563.4}{2}$ kJ mol^{-1} = 567.9 kJ
Energy from H_2 = $\frac{4.03}{2} \times \frac{483.6}{2}$ kJ mol^{-1} = 487.5 kJ
Total energy = 567.9 + 487.5 = 1055kJ

Question 24

Answer: D

Explanation:

Biodiesel contains polar carbon-oxygen bonds, which can form dipole-dipole bonds with water, causing a higher hygroscopicity and they have lower energy content per gram than petrodiesel.

Question 25

Answer: D

Explanation:

Twice as much hydrogen is produced at the cathode than oxygen at the anode. Hydrogen will emit a pop when tested with a splint.

Question 26

Answer: C

Explanation:

Carbohydrates with a greater percentage of amylose have a lower GI.

Question 27

Answer: C

Explanation:

Bromothymol blue has a colour change at a pH of 6.0-7.6 so would be suitable for a titration between a strong acid and a strong base.

Question 28

Answer: D

Explanation:

The greatest separation would be produced by a like stationary phase and an unlike mobile phase.

Question 29

Answer: B

Explanation:

Co-enzymes often bind with the active site, can carry electrons to assist a reaction and are not used in the reaction, but they are not proteins.

Question 30

Answer: A

Explanation:

$H_3O^+(aq)$ ions are produced in the recharge reaction at the anode, therefore the pH will decrease.

SECTION B: Short-answer questions

Question 1 (11 marks)

a. Energy content = $10.5 \times 37 + 0.7 \times 16 + 20.9 \times 17$*
=755kJ*

2 marks

b. Vitamin D is a fat-soluble vitamin as is a large molecule mainly non-polar molecule with only one hydroxyl group*. Therefore, it would not be suitable for a person to consume more than one serve of sardines in a day as the vitamin D would not be excreted and would accumulate in the body*.

2 marks

c.

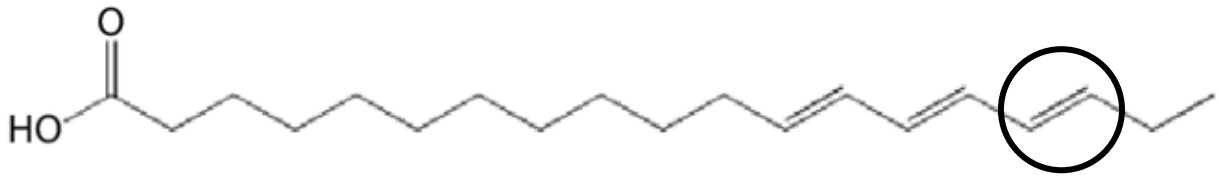
i. Alpha or 2-amino acids contain a carboxylic acid* and an amine group on the 2nd carbon*
2 mark

ii. Essential amino acids are amino acids that the body cannot produce from other amino acids*. Therefore, they must be consumed as part of an individual's diet*. 2 marks

d.

i. Linolenic acid. 1 mark

ii. 2 marks



Question 2

a. $C_3H_8(l) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ $\Delta H = -2220$ kJ mol^{-1}*

$2C_4H_{10}(l) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ $\Delta H = -5760$ kJ mol^{-1}*

2 marks

b. Energy from propane = $\frac{500\times60}{100} = 300$g

$\frac{300}{44} \times 2220 = 15136$kJ*

Energy from butane = $\frac{500\times40}{100} = 200$g

$\frac{200}{58} \times 2880 = 9931$kJ*

Total energy = 15136 + 9931 = 25067kJ*

3 marks

c. n(CO_2) from propane = $\frac{300}{44} \times 3 = 20.45$mol and

n(CO_2) from propane = $\frac{200}{58} \times 4 = 13.79$mol*

n(CO_2) = 34.24 mol *

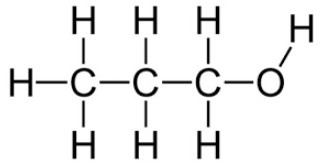
V(CO_2) = $34.24 \times 24.8 = 849$L*

3 marks

Question 3

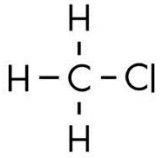
a. $H_3PO_4(aq)$ 1 mark

b.



1 mark

c. i.



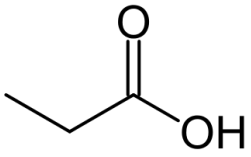
1 mark

ii. $CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$*

$\frac{50.5}{87} \times 100\% = 58.0\%$*

2 marks

d.



1 mark

e. Step 1

Oxidation: $C_3H_7OH(aq) \rightarrow C_3H_6O(aq) + 2H^+(aq) + 2e^-$

Reduction: $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$*(both equations)

Full: $3C_3H_7OH(aq) + Cr_2O_7^{2-}(aq) + 8H^+(aq) \rightarrow 3C_3H_6O(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$*

Step 2

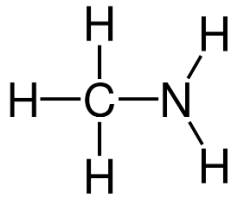
Oxidation: $C_3H_6O(aq) + H_2O(l) \rightarrow C_2H_5COOH(aq) + 2H^+(aq) + 2e^-$

Reduction: $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$*(both equations)

Full: $3C_3H_6O(aq) + Cr_2O_7^{2-}(aq) + 8H^+(aq) \rightarrow 3C_2H_5COOH\,(aq) + 2Cr^{3+}(aq) + 2H_2O(l)$*

4 marks

f.



1 mark

g.

Question 4

a.

	N_2	H_2	NH_3
Initial	$\frac{4}{0.5} = 8M$	$\frac{4}{0.5} = 8M$	0M
Change*	$\frac{5.2}{2} = -2.6M$	$\frac{5.2 \times 3}{2} = -7.8M$	+5.2M
Final*	5.4M	0.2M	5.2M

Kc = $\frac{5.2^2}{5.4 \times 0.2^3} = 626\text{M}^{-2}$*

3 marks

b. **i.** After the container was expanded the rate of the forward reaction decreased* as there were less collisions between N_2 and H_2 as there is more space in the container*.

2 marks

ii. C(N_2) = $\frac{5.4}{4} = 1.35M$, C(H_2) = $\frac{0.2}{4} = 0.05M$, C(NH_3)= $\frac{5.2}{4} = 1.3M$*

Kc = $\frac{1.3^2}{1.35 \times 0.05^3} = 10000\text{M}^{-2}$* (3 S.F.) 2 marks

iii. The reaction quotient is greater than the equilibrium constant*, therefore the reaction will move towards the left side until Q_c is equal to K_c*. 2 marks

c. **i.** High temperature increases the rate of reaction as there are more collisions between reactants with sufficient energy to overcome the activation energy.* High temperature will decrease the equilibrium constant as the reaction is exothermic, the reaction will move to the left side to absorb the energy*. 2 marks

ii. High pressure will increase the rate of reaction as there will be more collisions between reactants, therefore there would be more fruitful collisions*. High pressure will push the position of the equilibrium to the right as there are less molecules on the right, which will reduce the pressure in the vessel*. 2 marks

iii. A catalyst increases the rate of reaction as it reduces the energy required for a fruitful collision, therefore increasing the number of fruitful collisions*. A catalyst does not change the position of equilibrium as it increases the rate of the forward and backward reaction in equal proportions*. 2 marks

iv. High temperatures are favoured to ensure that the rate of production is high to produce ammonia quickly*. The low yield is overcome by reusing the unused reactants to produce more products*. 2 marks

Question 5

a. **i.** the small peak at 89 is caused by the presence of an isotope such as carbon-13.

1 mark

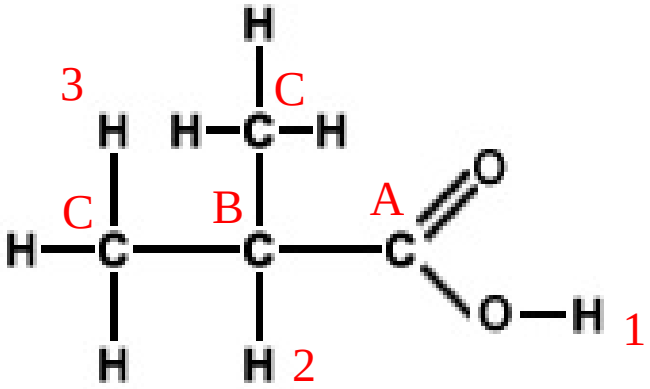
ii. $C_5H_{12}O$* or $C_4H_8O_2$* 2 marks

iii. base peak m/z 43 = $CH_3CH_2CH_2^+$ 1 mark

b. **i.** The spectra has a broad strong absorbance 2500-3500, indicative of OH acid*, and a strong narrow absorbance band at ~1700, indicative of C=O acid*. 2 marks

ii. $C_4H_8O_2$ 1 mark

c. **i, ii and iii**



3 marks

Question 6

a. **i.** anode = O_2*, cathode = H_2* **2** mark

ii. The cotton ball keeps the products of the reaction on each side of the U tube so the electrolyte can be tested. 1 mark

b. **i.** anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^{-*}$
cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$*
full equation: $2H_2O(l) + 2Cl^-(aq) \rightarrow Cl_2(g) + H_2(g) + 2OH^-(aq)$* 3 marks

ii. 20% m/v = 200g L^{-1}*
$C = \frac{200}{58.5} = 3.4M$* 2 marks

iii. Chloride ions are above water in the electrochemical series under standard conditions (1M solution)*, however when a highly concentrated sodium chloride solution is used the chloride half equation is preferred*. 2 marks

iv. $Q = 10000 \times 60 \times 60 \times 24 = 8.64 \times 10^8$*
$n(Cl_2) = \frac{8.64 \times 10^8}{96500} \times \frac{1}{2} = 4476.7$ mol*
$V(Cl_2) = \frac{4476.7 \times 8.31 \times 673}{250} = 100146L = 100ML$*
3 marks

c. **i.** calcium chloride is added to the electrolyte to reduce the melting point of the sodium chloride electrolyte.* This reduces the costs required to run the Downs cell.* 2 marks

ii. Calcium chloride does not affect the products of the electrolysis reaction as calcium is below sodium on the electrochemical series*. This means that the sodium reaction is preferred even if there is calcium present in the electrolyte. 2 marks

Question 7

a. volume of sodium hydroxide 1 mark

b. possible answers: parallax error reading burette, equipment error in pipette 1 mark

c. rinse burette with NaOH solution*
rinse conical flask with deionized water* 2 marks

d. The use of sodium hydroxide as a standard solution for the titration*, means that the accuracy and reliability of the investigation is questionable*. Sodium hydroxide absorbs carbon dioxide and water from the atmosphere, so it can not be used as primary standard solution*. It must be titrated against an acidic primary standard such as hydrochloric acid.* 4 marks.

Question 8

a. Incomplete combustion of octane produces 3206.5kJ mol^{-1}, whereas complete combustion produces 5460kJ mol^{-1}*. Therefore 70% more octane is required to produce the same energy through incomplete combustion, compared to complete combustion*. The complete combustion of octane produces carbon dioxide which contributes to climate change and increased acidity of oceans and rain*. Incomplete combustion produces carbon monoxide, which causes an exothermic reaction with oxygen to produce carbon dioxide, which contributes to the enhanced greenhouse effect and acid rain*.
4 marks

b. Carbon monoxide has adverse health implications as it binds to haemoglobin with a much higher equilibrium constant that oxygen*.

$$Hb(aq) + O_2(g) \rightleftharpoons HbO_2\ (aq) \qquad K_c \sim 1.2^*$$
$$Hb(aq) + CO(g) \rightleftharpoons HbCO\ (aq) \qquad K_c \sim 250^*$$

To treat carbon monoxide poisoning the patient must breathe in pure oxygen to bind with all available haemoglobin, which pushes the haemoglobin-carbon monoxide equilibrium to the left*. 4 marks.